# Lidar Mapping Report

## Acquisition, Processing, and Delivery of Airborne Lidar Elevation Data and Orthoimagery for NE_NRCS OrthoLidar-2017_D18 Project

**USGS CONTRACT:** G16PC00029

**CONTRACTOR:** Merrick-Surdex JV

**TASK ORDER NUMBER:** 014G0218F0028

**TASK NAME:** NE_NRCS OrthoLidar-2017_D18

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**TOTAL AWARD:** $2,340,632.27 (Fixed Price)

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## Glossary of Terms

| Term | Description |
|---|---|
| AGL | Above Ground Level |
| AGPS | Airborne Global Positioning System |
| ANPD | Aggregate Nominal Pulse Density |
| ANPS | Aggregate Nominal Pulse Spacing |
| ASPRS | American Society of Photogrammetry and Remote Sensing |
| AT | Aerial Triangulation |
| CD | Compact Disk |
| CMS | Certified Mapping Scientist |
| CORS | Continuous Operating Reference Station |
| CP | Certified Photogrammetrist |
| CVA | Consolidated Vertical Accuracy |
| DACS™ | Digital Airborne Camera System |
| DEM | Digital Elevation Model |
| DFIRM | Digital Flood Insurance Rate Maps |
| DSM | Digital Surface Model |
| DTM | Digital Terrain Model |
| DVD | Digital Versatile Disk / Digital Video Disk |
| DXF | Data Exchange Format / Drawing Interchange |
| FIRM | Flood Insurance Rate Maps |
| FEMA | Federal Emergency Management |
| FGDC | Federal Geographic Data Committee |
| FVA | Fundamental Vertical Accuracy |
| FY | Fiscal Year |
| GIS | Geographic Information System |
| GISP | Geographic Information System Professional |
| GNSS | Global Navigation Satellite System |
| GPS | Global Positioning System |
| GSD | Ground Sample Distance |
| HARN | High Accuracy Reference Network |
| HDD | Hard Drive Disk |
| HPGN | High Precision Geodetic Network |
| IMU | Inertial Measurement Unit |
| INS | Inertial Navigation System |
| LAS | (or .las) – industry accepted LIDAR data exchange file format |
| LB | License Business |
| LS | Land Surveyor |
| LiDAR | (or Lidar) Light Detection And Ranging |
| MARS® | Merrick Advanced Remote Sensing |
| Merrick | Merrick & Company |
| MSL | Mean Sea Level |
| NAD | North American Datum |
| NDEP | National Digital Elevation Program |
| NGP | National Geospatial Program |
| NGS | National Geodetic Survey |
| NMAS | National Map Accuracy Standards |
| No. | Number |
| NPS | Nominal Point Spacing |

| | |
|---|---|
| NSRS | National Spatial Reference System |
| NSSDA | National Standard for Spatial Data |
| NVA | Non-vegetated Vertical Accuracy |
| OPUS | Online Positioning User Service |
| PDOP | Positional Dilution Of Precision |
| PLS | Professional Land Surveyor |
| PLSS | Public Land Survey System |
| ppsm | Points (or pulses) per square meter |
| PSM | Professional Surveyor and Mapper |
| QL1 | Quality Level One |
| QL2 | Quality Level Two |
| RLS | Registered Land Surveyor |
| RGB | Red, Green, Blue (i.e., three-band image) |
| RGBNIR | Red, Green, Blue, Near Infra-Red (i.e., four-band image) |
| RMSE | Root Mean Square Error |
| SBET | Smoothed Best Estimated Trajectory |
| SHA | Secured Hash Standard |
| SPCS | State Plane Coordinate System |
| SVA | Supplemental Vertical Accuracy |
| TIN | Triangular Irregular Network |
| USGS | United State Geological Survey |
| VVA | Vegetated Vertical Accuracy |
| XML | eXtensible Markup Language |

## Project Summary

Merrick-Surdex Joint Venture, LLP (“Merrick-Surdex JV”) was awarded the NE_NRCS_OrthoLiDAR_2017_D18 project to provide high resolution elevation data derived from QL2 lidar over 11,110 square miles to include the Nebraska counties of Lincoln, Hayes, Frontier, Gosper, Red Willow, Furnas, Saunders, Butler, Platte, Colfax, Dodge, Fillmore, Saline, York, Seward, Otoe, Johnson, Nemaha, Pawnee and Richardson. Leaf-off, 4-band color and color near infrared imagery was captured at 60cm GSD, full DOQQ coverage or approximately 8,923 square miles for the Nebraska counties of Saunders, Butler, Platte, Colfax, Dodge, Fillmore, Saline, York, Seward, Otoe, Johnson, Nemaha, Pawnee and Richardson. This lidar data and leaf-off imagery will assist NE-NRCS in conservation planning, design, research, delivery, floodplain mapping, dam safety assessments, and hydrological modeling.

The lidar mapping requirements and deliverables meet Quality Level Two (QL2) standards for final deliverables as outlined in the USGS-NGP Lidar Base Specifications, Techniques and Methods 11–B4, Version **1.2**, November 2014 (TM11-B4). QL2 lidar specifications suggest a pulse density of greater than or equal to two pulses per square meter (≥2ppsm) Aggregate Nominal Pulse Density (ANPD), and pulse spacing of less than or equal to seventy-one centimeters (≤0.71m) Aggregate Nominal Pulse Spacing (ANPS). The orthoimagery horizontal accuracy meets or exceeds ≤4.0m at the 95% confidence level (2.31m RMSEr or 1.64m Horizontal Accuracy Class [RMSEx and RMSEy]).

The vertical accuracy requirements of the lidar data meets or exceeds the following:

<u>Vertical accuracy (absolute for the Non-Vegetated Vertical Accuracy [NVA])</u>

- ≤10cm RMSEz
- ≤19.6cm at the 95% confidence level (AccuracyZ)
- Vegetated Vertical Accuracy (VVA) ≤29.4cm at the 95% percentile

<u>Relative accuracy</u>

- ≤6cm Smooth surface repeatability
- ≤8cm RMSDz
- ±16cm maximum difference

This data set was produced to meet ASPRS “Positional Accuracy Standards for Digital Geospatial Data” (2014) for a 17.5 cm RMSEx / RMSEy Horizontal Accuracy Class which equates to Positional Horizontal Accuracy = +/- 42.8 cm at a 95% confidence level.

**Project Spatial Reference**

- Horizontal Datum – North American Datum of 1983 (NAD 83)
- Epoch – National Adjustment of 2011 (NA2011) (epoch 2010.00)
- Vertical Datum – North American Vertical Datum of 1988 (NAVD 88)
- Geoid – GEOID 12B
- Projection – UTM Zones 14N and 15N
- Units - Meters

**<u>CONTACT INFORMATION</u>**

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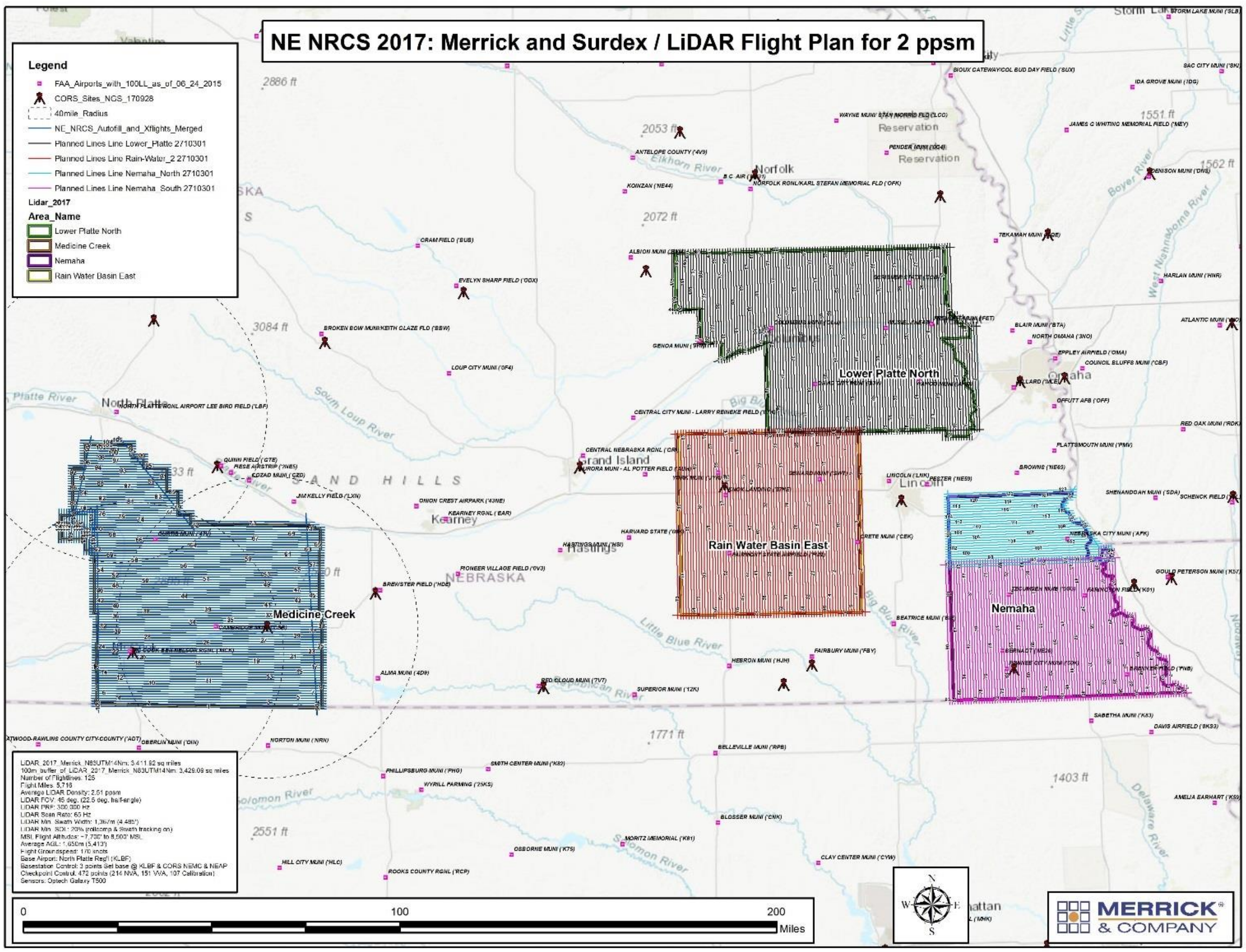
## Project Report

The contents of this report summarize the methods used to calibrate and classify the lidar data as well as the results of these methods for the project NE_NRCS_OrthoLiDAR_2017_D18.

### Lidar Flight Information

The acquisition area for the NE_NRCS_OrthoLiDAR_2017_D18 project is delineated by the extent of the client-approved Esri shapefiles (*Lidar_2017.shp*) and covers 11,110 square miles. Merrick-Surdex JV acquired the lidar point cloud utilizing an Optech Galaxy lidar sensors. The Galaxy is a high performance 550 kHz lidar sensor capable of collecting large areas efficiently.

Merrick-Surdex JV planned an acquisition area of approximately 11,110 square miles, to include a proper flight line orientation and numbers for accurate sensor calibration. See below illustration of the proposed lidar flight plan.



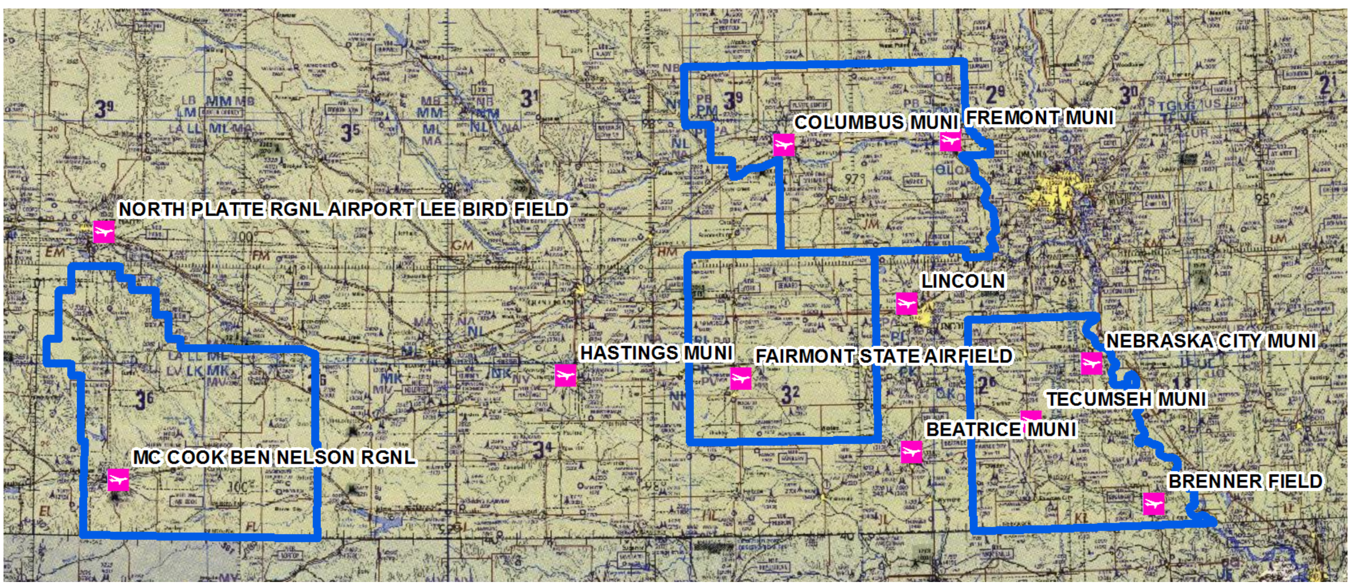
## Aerial Mission(s)

The lidar acquisition was collected using fixed wing aircraft and Optech Galaxy lidar sensors. Data collection for the project was accomplished between March 1, 2018 and May 7, 2018 using a variety of airports. Each mission represents a lift of the aircraft and system from the ground, collects data, and lands again. Multiple lifts within a day are represented by Mission A, B, C, and D. The table below relates each mission to the date collected, the sensor and serial number used, and the average MSL in meters.

| Mission(s) | Date | Sensor S/N | Actual Avg. MSL (m) |
|---|---|---|---|
| 180301_A | March 1, 2018 | 5060382 | 2275 |
| 180302_A | March 2, 2018 | 5060382 | 2300 |
| 180303_A | March 3, 2018 | 5060382 | 2300 |
| 180308_A | March 8, 2018 | 5060382 | 1918 |
| 180313_A | March 13, 2018 | 5060407 | 1919 |
| 180314_A | March 14, 2018 | 5060407 | 2349 |
| 180315_A | March 15, 2018 | 5060407 | 2391 |
| 180316_A | March 16, 2018 | 5060407 | 2151 |
| 180318_A | March 18, 2018 | 5060407 | 2167 |
| 180327_A | March 27, 2018 | 5060386 | 2550 |
| 180328_A | March 28, 2018 | 5060386 | 2500 |
| 180328_B | March 28, 2018 | 5060386 | 2580 |
| 180330_A | March 30, 2018 | 5060386 | 2470 |
| 180330_B | March 30, 2018 | 5060386 | 2460 |
| 180403_A | April 3, 2018 | 5060386 | 2456 |
| 180404_A | April 4, 2018 | 5060386 | 2432 |
| 180404_B | April 4, 2018 | 5060386 | 2420 |
| 180404_C | April 4, 2018 | 5060386 | 2400 |
| 180405_A | April 5, 2018 | 5060386 | 2380 |
| 180405_B | April 5, 2018 | 5060386 | 2394 |
| 180417_A | April 17, 2018 | 5060386 | 2402 |
| 180418_A | April 18, 2018 | 5060386 | 2420 |
| 180418_B | April 18, 2018 | 5060386 | 2400 |
| 180418_C | April 19, 2018 | 5060386 | 2458 |
| 180419_A | April 19, 2018 | 5060386 | 2450 |
| 180420_A | April 20, 2018 | 5060406 | 2333 |
| 180422_A | April 22, 2018 | 5060406 | 2403 |
| 180423_A | April 23, 2018 | 5060406 | 2341 |
| 180423_A | April 23, 2018 | 5060407 | 2334 |
| 180424_A | April 24, 2018 | 5060406 | 2424 |
| 180424_A | April 24, 2018 | 5060407 | 2479 |
| 180426_A | April 26, 2018 | 5060407 | 2512 |
| 180426_A | April 26, 2018 | 5060406 | 2439 |

| | | | |
|---|---|---|---|
| 180427_A | April 27, 2018 | 5060382 | 2509 |
| 180427_A | April 27, 2018 | 5060406 | 2459 |
| 180427_A | April 27, 2018 | 5060407 | 2483 |
| 180428_A | April 28, 2018 | 5060406 | 2334 |
| 180428_A | April 28, 2018 | 5060407 | 2485 |
| 180428_A | April 28, 2018 | 5060382 | 2509 |
| 180429_A | April 29, 2018 | 5060406 | 2382 |
| 180504_A | May 4, 2018 | 5060407 | 2460 |
| 180504_A | May 4, 2018 | 5060406 | 2452 |
| 180505_A | May 5, 2018 | 5060406 | 2421 |
| 180505_A | May 5, 2018 | 5060407 | 2526 |
| 180505_A | May 5, 2018 | 5060382 | 2473 |
| 180506_A | May 6, 2018 | 5060406 | 2427 |
| 180506_A | May 6, 2018 | 5060382 | 2471 |
| 180506_A | May 6, 2018 | 5060407 | 2495 |
| 180507_A | May 7, 2018 | 5060406 | 2462 |
| 180507_A | May 7, 2018 | 5060407 | 2447 |

**Airports Used**




## GNSS / IMU Data

A five-minute INS initialization is conducted on the ground, with the aircraft engines running, prior to flight, to establish fine-alignment of the INS. GPS ambiguities are resolved by flying within ten kilometers of the base stations. During the data collection, the operator recorded information on log sheets which includes weather conditions, lidar operation parameters, and flight line statistics. Near the end of the mission, GPS ambiguities were again resolved by flying within ten kilometers of the base stations to aid in post-processing. Data is sent back to the main office for preliminary processing to check overall quality of GPS / INS data and to ensure sufficient overlap between flight lines. Any problematic data may be re-flown immediately as required.

The airborne GPS data was post-processed using Applanix POSPac Mobile Mapping Suite version 8.x. A fixed-bias carrier phase solution was computed in both the forward and reverse chronological directions. Whenever practical, lidar acquisition was limited to periods when the PDOP was less than 4.0. PDOP indicates satellite geometry relating to position. Generally, PDOP's of 4.0 or less result in a good quality solution, however PDOP's between 4.0 and 5.0 can still yield good results most of the time. PDOP's over 6.0 are of questionable results and PDOP's of over 7.0 usually result in a poor solution. Usually as the number of satellites increase the PDOP decreases. Other quality control checks used for the GPS include analyzing the combined separation of the forward and reverse GPS processing from one base station and the results of the combined separation when processed from two different base stations. An analysis of the number of satellites, present during the flight and data collection times, is also performed.

The GPS trajectory was combined with the raw IMU data and post-processed using POSPac Mobile Mapping Suite version 8.x. The SBET and refined attitude data are then utilized in the LMS Post Processor to compute the laser point-positions – the trajectory is combined with the attitude data and laser range measurements to produce the 3-dimensional coordinates of the mass points. Up to four return values are produced within the Optech LMS processor software for each pulse which ensures the greatest chance of ground returns in a heavily forested area.

## GPS Controls

Ground GNSS Base Stations were set up to control the lidar airborne flight lines. In addition, CORS are at times used to further enhance the airborne solution. The ground GNSS Base Stations coordinates were obtained from NGS OPUS solutions. CORS coordinates were obtained from NGS datasheets.

## **Lidar Calibration –** see appendix 1 for a more detailed workflow description

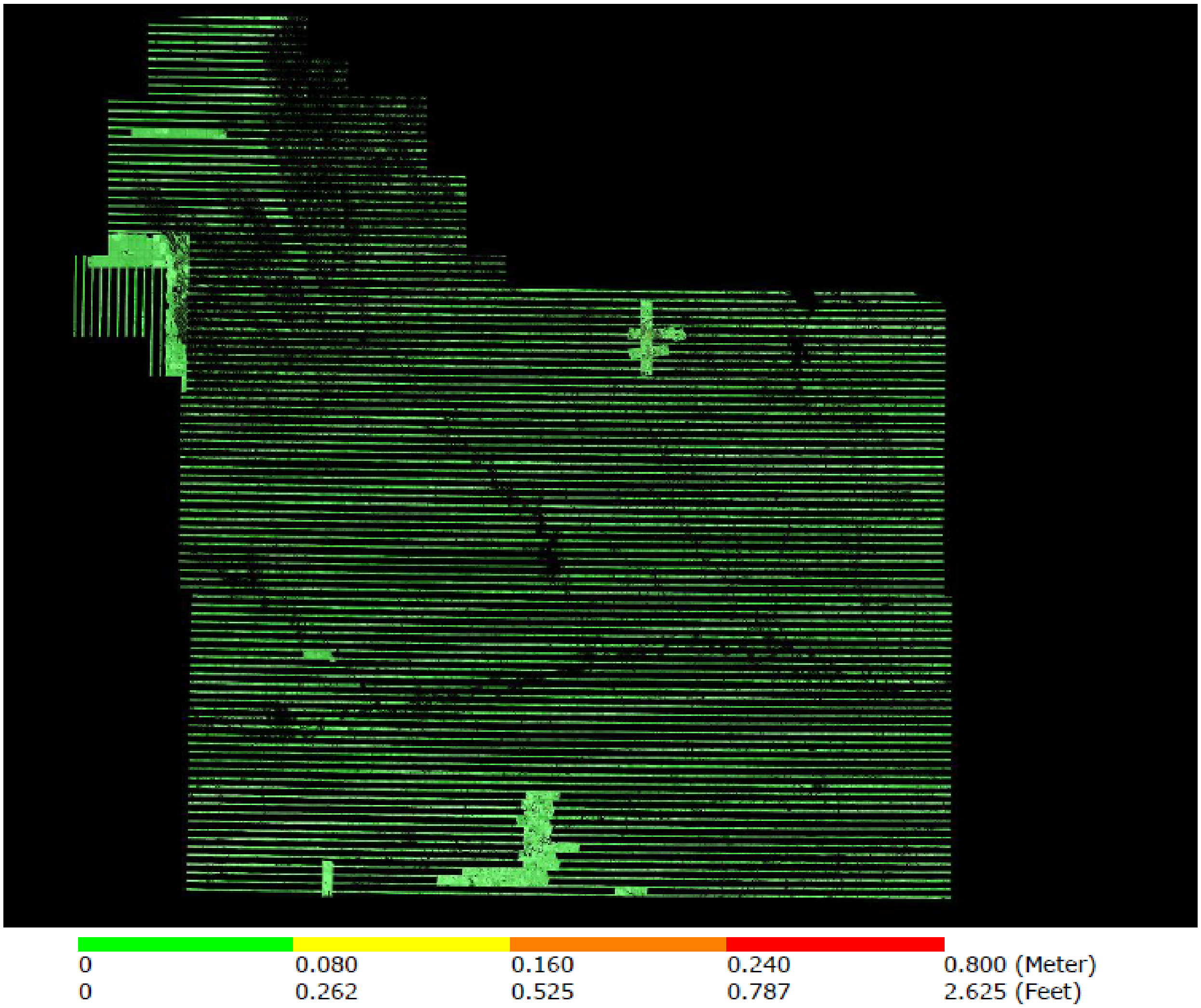
Merrick-Surdex JV takes great care to ensure all lidar acquisition missions are carried out in a manner conducive to post-processing an accurate data set. This begins in the flight-planning stage with attention to GPS baseline distances and GPS satellite constellation geometry and outages. Proper AGPS surveying techniques are always followed including pre- and post-mission static initializations. In-air IMU alignments (figure-eights) are performed both before and after on-site collection to ensure proper calibration of the IMU accelerometers and gyros.

A minimum of one cross-flight is planned throughout the project area across all flightlines and over roadways where possible. The cross-flight provides a common control surface used to remove any vertical discrepancies in the lidar data between flightlines. The cross-flight is critical to ensure flightline ties across the project area. The areas of overlap between flightlines are used to boresight (calibrate) the lidar point cloud to achieve proper flightline to flightline alignment in all three axes. This includes adjustment of both IMU and scanner-related variables such as roll, pitch, heading, timing interval (range), and torsion. Each lidar mission flown is accompanied by a hands-on boresight in the office.

After boresighting is complete a detailed statistical report is generated to check relative and absolute accuracies before filtering of lidar begins.

### Relative Accuracy – flight line to flight line

The project representative flight line separation raster example (below) depicts the vertical separation of flight lines by thematically coloring the separation magnitude on a color ramp based on relative distance.




### Survey – Lidar / Imagery Control

CompassData, Inc. surveyors established lidar control points, lidar checkpoints and photo identifiable points spatially distributed across the project AOI as the method to validate absolute vertical accuracy of the lidar and radial horizontal accuracy of the imagery.

*See appendix 3 – Survey Report.*

### Unfiltered Lidar Control Point Report

The following tables illustrate the results of the lidar data compared to the lidar control points post-calibration. The listing is sorted by the Z Error column showing, in ascending order, the vertical difference between the lidar points and the 124 surveyed ground points (110 control points within UTM14 / 14 control points within UTM15) used for lidar calibration.

## UTM 14 Control

Project Data Unit: Meter
Vertical Accuracy Class tested: 10.0-cm
Elevation Calculation Method: Interpolated from TIN
LiDAR Classifications Included: 2/0 Ground (All)/0W

Check Points in Report: 110
Check Points with LiDAR Coverage: 110
Check Points (NVA): 110
Check Points (VVA): 0
Average Vertical Error Reported: -0.002 Meter
Maximum (highest) Vertical Error Reported: 0.081 Meter
Median Vertical Error Reported: 0.002 Meter
Minimum (lowest) Vertical Error Reported: -0.202 Meter
Standard deviation of Vertical Error: 0.039 Meter
Skewness of Vertical Error: -1.730
Kurtosis of Vertical Error: 6.410
Non-vegetated Vertical Accuracy (NVA) RMSE(z): 3.871cm PASS
Non-vegetated Vertical Accuracy (NVA) at the 95% Confidence Level +/-: 7.587cm PASS
FGDC/NSSDA Vertical Accuracy at the 95% Confidence Level +/-: 7.587cm
Non-vegetated Vertical Accuracy (NVA) RMSE(z) (DEM): 4.193cm PASS
Non-vegetated Vertical Accuracy (NVA) at the 95% Confidence Level +/- (DEM): 8.219cm PASS

This data set was tested to meet ASPRS Positional Accuracy Standard for Digital Geospatial Data (2014) for a 10.0-cm RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be RMSEz = 3.871cm, equating to +/- 7.587cm at the 95% confidence level.

| Check Point Id | Check Point X | Check Point Y | Coverage | Check Point Z | Z from LiDAR | Z Error |
|---|---|---|---|---|---|---|
| CAL3005 | 667416.801 | 4561114.577 | Yes | 509.642 | 509.649 | 0.007 |
| CAL3008 | 656594.838 | 4569821.799 | Yes | 496.807 | 496.788 | -0.019 |
| CAL3008_alt | 656664.505 | 4569600.391 | Yes | 496.163 | 496.181 | 0.018 |
| CAL3029 | 666340.051 | 4549967.753 | Yes | 495.378 | 495.235 | -0.143 |
| CAL3111 | 642965.786 | 4562472.168 | Yes | 483.569 | 483.566 | -0.003 |
| CAL3002 | 662080.932 | 4589443.538 | Yes | 412.212 | 412.246 | 0.034 |
| CAL3007 | 674516.863 | 4607206.849 | Yes | 462.557 | 462.589 | 0.032 |
| CAL3021 | 649077.179 | 4595420.032 | Yes | 451.028 | 451.041 | 0.013 |
| CAL3022 | 656077.24 | 4620664.619 | Yes | 464.769 | 464.803 | 0.034 |
| CAL_COLFAX_EXTRA | 661773.175 | 4605319.462 | Yes | 457.372 | 457.339 | -0.033 |
| CAL3004 | 685381.923 | 4593165.005 | Yes | 387.691 | 387.62 | -0.071 |
| CAL3009 | 675961.589 | 4620917.03 | Yes | 427.078 | 427.145 | 0.067 |
| CAL3012 | 707732.237 | 4623144.461 | Yes | 397.157 | 397.151 | -0.006 |
| CAL3015 | 711868.624 | 4589352.769 | Yes | 359.018 | 359.088 | 0.07 |
| CAL3019 | 694412.965 | 4614849.195 | Yes | 381.65 | 381.579 | -0.071 |
| CAL3027 | 711004.609 | 4601199.272 | Yes | 366.64 | 366.659 | 0.019 |
| CAL_DODGE_EXTRA | 691568.236 | 4601962.038 | Yes | 410.247 | 410.265 | 0.018 |
| CAL3003 | 619281.234 | 4615177.049 | Yes | 525.532 | 525.52 | -0.012 |
| CAL3011 | 640599.128 | 4616203.153 | Yes | 500.515 | 500.534 | 0.019 |
| CAL3017 | 625892.02 | 4583313.994 | Yes | 456.783 | 456.818 | 0.035 |
| CAL3020 | 616766.884 | 4592552.447 | Yes | 464.531 | 464.568 | 0.037 |
| CAL3024 | 608607.956 | 4605992.393 | Yes | 535.067 | 535.089 | 0.022 |
| CAL3028 | 635731.749 | 4588623.154 | Yes | 441.899 | 441.697 | -0.202 |
| CAL_extra_platte | 627728.172 | 4620847.869 | Yes | 506.6 | 506.629 | 0.029 |

| | | | | | | |
|---|---|---|---|---|---|---|
| CAL3006 | 718101.445 | 4568714.486 | Yes | 356.072 | 356.076 | 0.004 |
| CAL3010 | 697061.77 | 4548048.91 | Yes | 380.77 | 380.752 | -0.018 |
| CAL3013 | 700221.22 | 4574515.918 | Yes | 381.2 | 381.112 | -0.088 |
| CAL3014 | 709818.31 | 4548392.541 | Yes | 373.417 | 373.413 | -0.004 |
| CAL3016 | 716114.571 | 4555022.368 | Yes | 350.049 | 350.04 | -0.009 |
| CAL3023 | 686063.094 | 4583287.547 | Yes | 407.894 | 407.892 | -0.002 |
| CAL3025 | 685121.847 | 4559104.39 | Yes | 420.721 | 420.734 | 0.013 |
| CAL3108 | 721186.751 | 4546793.916 | Yes | 329.088 | 329.017 | -0.071 |
| CAL_EXTRA_SAU | 698593.744 | 4561103.559 | Yes | 387.538 | 387.58 | 0.042 |
| CAL3034 | 606065.813 | 4486732.136 | Yes | 509.654 | 509.683 | 0.029 |
| CAL3036 | 618909.943 | 4486894.638 | Yes | 500.931 | 500.901 | -0.03 |
| CAL3038 | 631286.863 | 4500427.906 | Yes | 489.788 | 489.81 | 0.022 |
| CAL3043 | 608299.548 | 4474970.732 | Yes | 502.495 | 502.518 | 0.023 |
| CAL3047 | 602684.937 | 4498013.685 | Yes | 510.871 | 510.897 | 0.026 |
| CAL3051 | 620768.091 | 4469251.703 | Yes | 486.638 | 486.653 | 0.015 |
| CAL3030 | 659407.143 | 4501386.554 | Yes | 452.533 | 452.524 | -0.009 |
| CAL3031 | 672737.85 | 4483712.205 | Yes | 405.394 | 405.391 | -0.003 |
| CAL3040 | 653205.702 | 4473009.202 | Yes | 455.218 | 455.209 | -0.009 |
| CAL3042 | 676070.544 | 4473810.558 | Yes | 394.026 | 393.999 | -0.027 |
| CAL3042_alt | 676277.753 | 4473841.213 | Yes | 393.179 | 393.174 | -0.005 |
| CAL3046 | 674675.309 | 4500835.445 | Yes | 442.314 | 442.249 | -0.065 |
| CAL3048 | 644755.545 | 4501424.085 | Yes | 474.235 | 474.246 | 0.011 |
| CAL3049 | 641266.292 | 4475585.445 | Yes | 489.276 | 489.289 | 0.013 |
| CAL3049_alt | 641158.85 | 4475545.866 | Yes | 489.113 | 489.14 | 0.027 |
| CAL3001 | 663378.608 | 4541263.909 | Yes | 475.402 | 475.433 | 0.031 |
| CAL3018 | 638734.138 | 4545279.45 | Yes | 494.482 | 494.563 | 0.081 |
| CAL3032 | 663876.835 | 4515409.457 | Yes | 450.413 | 450.422 | 0.009 |
| CAL3033 | 669593.297 | 4534555.984 | Yes | 480.038 | 480.08 | 0.042 |
| CAL3035 | 644937.607 | 4515595.32 | Yes | 445.789 | 445.758 | -0.031 |
| CAL3039 | 639062.755 | 4527803.941 | Yes | 483.643 | 483.676 | 0.033 |
| CAL3045 | 659294.224 | 4529996.02 | Yes | 439.366 | 439.415 | 0.049 |
| CAL3109 | 650794.425 | 4545481.826 | Yes | 457.685 | 457.67 | -0.015 |
| CAL3110 | 673978.234 | 4545941.814 | Yes | 444.285 | 444.287 | 0.002 |
| CAL_extra_sew | 674268.027 | 4534671.783 | Yes | 449.676 | 449.678 | 0.002 |
| CAL3037 | 618781.515 | 4524927.766 | Yes | 487.606 | 487.629 | 0.023 |
| CAL3041 | 634339.585 | 4542991.279 | Yes | 492.327 | 492.31 | -0.017 |
| CAL3044 | 606704.677 | 4539866.952 | Yes | 528.472 | 528.511 | 0.039 |
| CAL3050 | 600553.467 | 4515315.223 | Yes | 523.819 | 523.806 | -0.013 |
| CAL_extra_york | 618095.128 | 4520039.281 | Yes | 502.659 | 502.598 | -0.061 |
| CAL3052 | 360195.02 | 4479229.163 | Yes | 862.2 | 862.213 | 0.013 |
| CAL3055 | 407068.083 | 4472171.017 | Yes | 725.404 | 725.355 | -0.049 |
| CAL3062 | 361209.138 | 4501939.753 | Yes | 864.135 | 864.122 | -0.013 |
| CAL3068 | 381723.323 | 4504789.334 | Yes | 861.476 | 861.46 | -0.016 |
| CAL3070 | 387678.987 | 4479152.406 | Yes | 785.137 | 785.108 | -0.029 |
| CAL3071 | 407479.145 | 4502821.811 | Yes | 813.436 | 813.435 | -0.001 |

| | | | | | | |
|---|---|---|---|---|---|---|
| CAL3074 | 408797.299 | 4483742.365 | Yes | 766.757 | 766.716 | -0.041 |
| CAL3076 | 376753.914 | 4500009.425 | Yes | 815.35 | 815.365 | 0.015 |
| CAL3082 | 395878.986 | 4488357.913 | Yes | 784.974 | 785.001 | 0.027 |
| CAL3054 | 417723.323 | 4462367.604 | Yes | 669.755 | 669.747 | -0.008 |
| CAL3063 | 445550.108 | 4449085.271 | Yes | 686.967 | 686.971 | 0.004 |
| CAL3066 | 437512.146 | 4429851.649 | Yes | 690.814 | 690.843 | 0.029 |
| CAL3069 | 411195.948 | 4440535.034 | Yes | 693.349 | 693.317 | -0.032 |
| CAL3077 | 402974.822 | 4431553.6 | Yes | 754.548 | 754.523 | -0.025 |
| CAL3078 | 433674.84 | 4462389.587 | Yes | 686.478 | 686.489 | 0.011 |
| CAL3080 | 423922.947 | 4437990.42 | Yes | 715.972 | 715.951 | -0.021 |
| CAL3058 | 426234.5 | 4491327.595 | Yes | 779.069 | 779.044 | -0.025 |
| CAL3072 | 424804.167 | 4481592.172 | Yes | 737.544 | 737.575 | 0.031 |
| CAL3073 | 443971.402 | 4494334.986 | Yes | 756.654 | 756.66 | 0.006 |
| CAL3084 | 443808.71 | 4470116.512 | Yes | 711.096 | 711.121 | 0.025 |
| CAL3075 | 336066.579 | 4503706.775 | Yes | 889.967 | 889.98 | 0.013 |
| CAL3059 | 352400.922 | 4534859.009 | Yes | 928.523 | 928.555 | 0.032 |
| CAL3061 | 369990.252 | 4524831.682 | Yes | 921.738 | 921.717 | -0.021 |
| CAL3064 | 355614.223 | 4509680.507 | Yes | 873.353 | 873.332 | -0.021 |
| CAL3065 | 380780.298 | 4517214.337 | Yes | 903.708 | 903.711 | 0.003 |
| CAL3053 | 367504.497 | 4430742.083 | Yes | 802.952 | 802.95 | -0.002 |
| CAL3056 | 352265.775 | 4430578.838 | Yes | 881.146 | 881.174 | 0.028 |
| CAL3057 | 381715.726 | 4441742.437 | Yes | 807.947 | 807.945 | -0.002 |
| CAL3060 | 359670.898 | 4460283.163 | Yes | 834.101 | 834.144 | 0.043 |
| CAL3067 | 361158.944 | 4446271.021 | Yes | 767.38 | 767.405 | 0.025 |
| CAL3079 | 351775.823 | 4453212.571 | Yes | 775.148 | 775.183 | 0.035 |
| CAL3081 | 387908.305 | 4434341.233 | Yes | 735.637 | 735.632 | -0.005 |
| CAL3083 | 390281.426 | 4456650.822 | Yes | 709.32 | 709.285 | -0.035 |
| CAL3086 | 722338.717 | 4482676.762 | Yes | 377.866 | 377.866 | 0 |
| CAL3102 | 719158.678 | 4468119.691 | Yes | 391.408 | 391.432 | 0.024 |
| CAL3114 | 744079.729 | 4463539.449 | Yes | 329.028 | 329.045 | 0.017 |
| CAL3098 | 754741.01 | 4477877.984 | Yes | 376.979 | 376.946 | -0.033 |
| CAL3087 | 752232.338 | 4490996.408 | Yes | 301.621 | 301.617 | -0.004 |
| CAL3095 | 718103.415 | 4514727.992 | Yes | 396.222 | 396.198 | -0.024 |
| CAL3099 | 738395.317 | 4504515.557 | Yes | 338.54 | 338.527 | -0.013 |
| CAL3100 | 738178.864 | 4515804.218 | Yes | 362.461 | 362.462 | 0.001 |
| CAL3105 | 752777.065 | 4512687.947 | Yes | 355.391 | 355.345 | -0.046 |
| CAL3112 | 729278.003 | 4489318.046 | Yes | 349.816 | 349.807 | -0.009 |
| CAL3085 | 720231.639 | 4457919.89 | Yes | 445.709 | 445.665 | -0.044 |
| CAL3092 | 742523.222 | 4444000.589 | Yes | 365.9 | 365.911 | 0.011 |
| CAL3096 | 751876.585 | 4435650.717 | Yes | 323.967 | 323.951 | -0.016 |
| CAL3107 | 719565.347 | 4435887.619 | Yes | 425.371 | 425.333 | -0.038 |

## UTM 15 Control

Project Data Unit: Meter
Vertical Accuracy Class tested: 10.0-cm
Elevation Calculation Method: Interpolated from TIN
LiDAR Classifications Included: 2/0 Ground (All)/0W

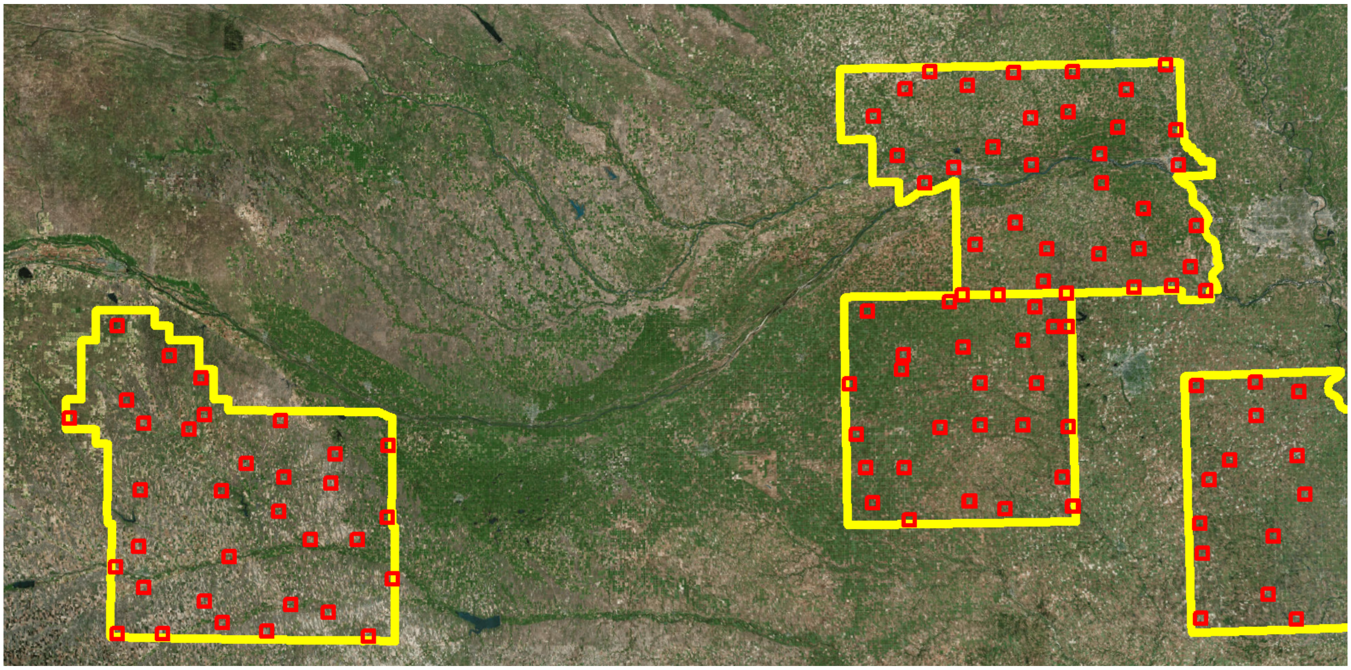
Check Points in Report: 14
Check Points with LiDAR Coverage: 14
Check Points (NVA): 14
Check Points (VVA): 0
Average Vertical Error Reported: -0.011 Meter
Maximum (highest) Vertical Error Reported: 0.062 Meter
Median Vertical Error Reported: -0.011 Meter
Minimum (lowest) Vertical Error Reported: -0.066 Meter
Standard deviation of Vertical Error: 0.039 Meter
Skewness of Vertical Error: 0.331
Kurtosis of Vertical Error: -1.056
Non-vegetated Vertical Accuracy (NVA) RMSE(z): 3.951cm PASS
Non-vegetated Vertical Accuracy (NVA) at the 95% Confidence Level +/-: 7.745cm PASS
FGDC/NSSDA Vertical Accuracy at the 95% Confidence Level +/-: 7.745cm
Non-vegetated Vertical Accuracy (NVA) RMSE(z) (DEM): 4.751cm PASS
Non-vegetated Vertical Accuracy (NVA) at the 95% Confidence Level +/- (DEM): 9.312cm PASS

This data set was tested to meet ASPRS Positional Accuracy Standard for Digital Geospatial Data (2014) for a 10.0-cm RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be RMSEz = 3.951cm, equating to +/- 7.745cm at the 95% confidence level.

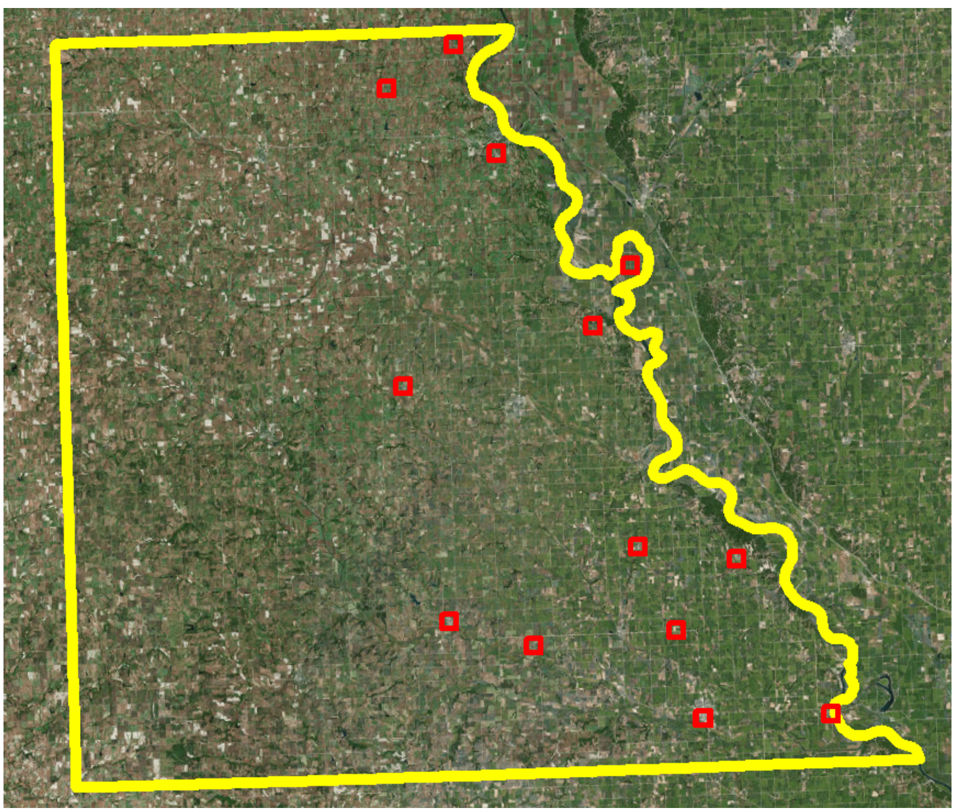
| Check Point Id | Check Point X | Check Point Y | Coverage | Check Point Z | Z from LiDAR | Z Error |
|---|---|---|---|---|---|---|
| CAL3098 | 245640.847 | 4477865.01 | Yes | 376.979 | 376.946 | -0.033 |
| CAL3101 | 268235.859 | 4483377.538 | Yes | 334.84 | 334.879 | 0.039 |
| CAL3113 | 273131.346 | 4490116.178 | Yes | 276.053 | 276.048 | -0.005 |
| CAL3094 | 258320.466 | 4504308.325 | Yes | 320.741 | 320.702 | -0.039 |
| CAL3103 | 254261.71 | 4517266.11 | Yes | 332.087 | 332.035 | -0.052 |
| CAL3105 | 246051.673 | 4512727.997 | Yes | 355.391 | 355.345 | -0.046 |
| CAL3088 | 271753.215 | 4457266.815 | Yes | 342.796 | 342.858 | 0.062 |
| CAL3090 | 275624.765 | 4447237.837 | Yes | 311.072 | 311.077 | 0.005 |
| CAL3091 | 278036.156 | 4436781.307 | Yes | 287.212 | 287.146 | -0.066 |
| CAL3091_alt | 278061.362 | 4436760.551 | Yes | 285.504 | 285.451 | -0.053 |
| CAL3093 | 293024.25 | 4436356.333 | Yes | 270.734 | 270.73 | -0.004 |
| CAL3097 | 249199.771 | 4450089.697 | Yes | 312.133 | 312.163 | 0.03 |
| CAL3104 | 258830.482 | 4446616.447 | Yes | 318.683 | 318.667 | -0.016 |
| CAL3106 | 283262.665 | 4455134.453 | Yes | 343.278 | 343.304 | 0.026 |

## Lidar Control Point Layout

### UTM 14



### UTM 15



## Lidar Filtering and Classification

The lidar filtering process encompasses a series of automated and manual steps to classify the boresighted point cloud data set. Each project represents unique characteristics in terms of cultural features (urbanized vs. rural areas), terrain type and vegetation coverage. These characteristics are thoroughly evaluated at the onset of the project to ensure that the appropriate automated filters are applied and that subsequent manual filtering yields correctly classified data. Data is most often classified by ground and "unclassified", but specific project applications can include a wide variety of classifications including but not limited to buildings, vegetation, power lines, etc. MARS® software is used for the auto-filtering, manual filtering and QC of the classified data.

Merrick-Surdex JV used the ASPRS LAS Specification Version 1.4 – R13, 15 July 2013, Point Data Record Format 6 for this project and classified the lidar point cloud in accordance with the following classification classes and bitflags. The following outlines project specific requirements.

- Class 1 = Unclassified
- Class 2 = Bare-earth Ground
- Class 7 = Low point (noise)
- Class 9 = Water
- Class 10 = Ignored ground (near a breakline)
- Class 17 = Bridge decks
- Class 18 = High noise
- Bitflags
    - Withheld: Within the LAS file specification, a single bit flag indicating that the associated lidar point is geometrically anomalous or unreliable and should be ignored for all normal processes.
    - Traditional Class 8 (Model Keypoints) points moved to Class 2, and are flagged using the bit flags.
    - Overlap points will be flagged using bit flags.

Merrick-Surdex JV has developed several customized automated filters that are applied to the lidar data set based on project specifications, terrain, and vegetation characteristics. A filtering macro, which may contain one or more filtering algorithms, is executed to derive LAS files separated into the different classification groups as defined in the ASPRS classification table. The macros are tested in several portions of the project area to verify the appropriateness of the filters. Often, there is a combination of several filter macros that optimize the filtering based on the unique characteristics of the project. Automatic filtering generally yields a ground surface that is 85-90% valid, so additional editing (hand-filtering) is required to produce a more robust ground surface.

Lidar data is next taken into a graphic environment using MARS® to manually re-classify (or hand-filter) "noise" and other features that may remain in the ground classification after auto filter. A cross-section of the post auto-filtered surface is viewed to assist in the reclassification of non-ground data artifacts. The following is an example of re-classification of the non-ground points (elevated features) that need to be excluded from the true ground surface. Certain features such as berms, hilltops, cliffs and other features may have been aggressively auto-filtered and points will need to be re-classified into the ground classification. Data in the profile view displays non-ground (Unclassified, class 1) in grey and ground in brown/tan (Class 2). In figure 1, a small building was not auto-filtered and needs to be manually re-classified. Note that figure 2 has the building points reclassified to unclassified from the true ground surface.

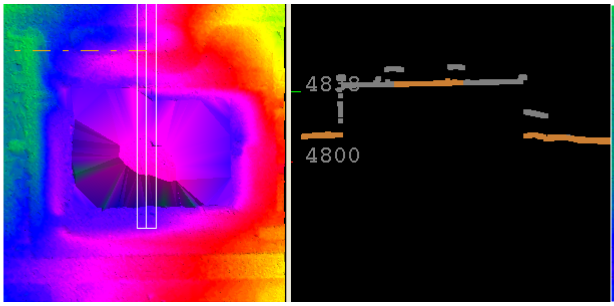



**Figure 1**

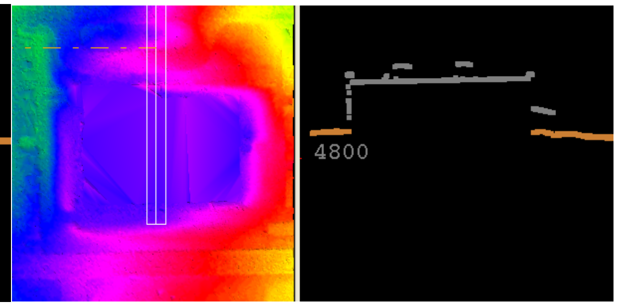



**Figure 2**

A combination of automated and semi-automated routines to classify buildings and vegetation. We expect that the classified buildings will meet a filtering criterion in the range of 90-95%.

At this point, individual lidar points from the original point cloud have now been parsed into separate classifications.

### Filtered Lidar Checkpoint Report

After hand-filtering has been completed and quality checked, a Checkpoint Report is generated to validate that the accuracy of the ground surface is within the defined accuracy specifications. Each surveyed ground check point is compared to the lidar surface by interpolating an elevation from a Triangulated Irregular Network (TIN) of the surface. The MARS® derived report provides an in-depth statistical report, including an RMSE of the vertical errors; a primary component in most accuracy standards and a statistically valid assessment of the overall accuracy of the ground surface.

The below lidar check point reports provide statistics for 391 ground survey points used to validate the final filtered lidar surface.

Project Data Unit: Meter
Vertical Accuracy Class tested: 10.0-cm
Elevation Calculation Method: Interpolated from TIN
LiDAR Classifications Included: 2,8/0 Ground (All)/0W

Check Points in Report: 391
Check Points with LiDAR Coverage: 391
Check Points (NVA): 231
Check Points (VVA): 160
Average Vertical Error Reported: 0.003 Meter
Maximum (highest) Vertical Error Reported: 0.136 Meter
Median Vertical Error Reported: 0.004 Meter
Minimum (lowest) Vertical Error Reported: -0.135 Meter
Standard deviation of Vertical Error: 0.037 Meter
Skewness of Vertical Error: -0.381
Kurtosis of Vertical Error: 1.192
Non-vegetated Vertical Accuracy (NVA) RMSE(z): 3.742cm PASS
Non-vegetated Vertical Accuracy (NVA) at the 95% Confidence Level +/-: 7.335cm PASS
Vegetated Vertical Accuracy (VVA) at the 95th Percentile +/-: 14.250cm PASS
FGDC/NSSDA Vertical Accuracy at the 95% Confidence Level +/-: 7.335cm
Non-vegetated Vertical Accuracy (NVA) RMSE(z) (DEM): 3.856cm PASS
Non-vegetated Vertical Accuracy (NVA) at the 95% Confidence Level +/- (DEM): 7.558cm PASS
Vegetated Vertical Accuracy (VVA) at the 95th Percentile +/- (DEM): 13.440cm PASS

This data set was tested to meet ASPRS Positional Accuracy Standard for Digital Geospatial Data (2014) for a 10.0-cm RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be RMSEz = 3.742cm, equating to +/- 7.335cm at the 95% confidence level. Actual VVA accuracy was fo und to be +/- 14.250cm at the 95th percentile.

| Checkpoint Id | Checkpoint X | Checkpoint Y | Checkpoint Z | Z from lidar | Z Error | Type |
|---|---|---|---|---|---|---|
| NVA_COLFAX_EXTRA | 661876.733 | 4602027.806 | 433.48 | 433.439 | -0.041 | NVA |
| NVA_DODGE_EXTRA | 691584.12 | 4600727.402 | 391.487 | 391.507 | 0.02 | NVA |
| NVA_EXTRA_SAU | 698571.333 | 4562777.689 | 380.164 | 380.22 | 0.056 | NVA |
| NVA1001 | 708058.685 | 4609581.785 | 370.399 | 370.43 | 0.031 | NVA |
| NVA1002 | 666137.828 | 4550001.516 | 495.715 | 495.613 | -0.102 | NVA |
| NVA1003 | 678507.181 | 4565438.184 | 457.384 | 457.457 | 0.073 | NVA |
| NVA1004 | 626415.176 | 4599776.804 | 476.169 | 476.213 | 0.044 | NVA |
| NVA1005 | 669788.233 | 4602227.012 | 437.393 | 437.289 | -0.104 | NVA |
| NVA1006 | 682120.492 | 4549957.904 | 399.071 | 399.08 | 0.009 | NVA |
| NVA1007 | 667599.348 | 4560281.948 | 508.398 | 508.389 | -0.009 | NVA |
| NVA1008 | 713846.537 | 4577522.16 | 368.916 | 368.976 | 0.06 | NVA |
| NVA1009 | 715530.693 | 4552478.319 | 335.332 | 335.468 | 0.136 | NVA |
| NVA1010 | 640729.608 | 4588930.649 | 437.305 | 437.356 | 0.051 | NVA |
| NVA1011 | 695063.253 | 4614971.549 | 381.124 | 381.129 | 0.005 | NVA |
| NVA1012 | 636369.747 | 4618490.926 | 501.34 | 501.377 | 0.037 | NVA |
| NVA1013 | 683889.093 | 4619501.598 | 410.741 | 410.742 | 0.001 | NVA |
| NVA1014 | 708682.536 | 4591894.728 | 363.972 | 363.964 | -0.008 | NVA |
| NVA1015 | 636076.522 | 4601633.928 | 493.925 | 493.929 | 0.004 | NVA |
| NVA1016 | 700279.239 | 4574721.609 | 379.864 | 379.729 | -0.135 | NVA |
| NVA1017 | 718059.113 | 4568540.542 | 356.847 | 356.843 | -0.004 | NVA |
| NVA1018 | 605424.797 | 4605922.804 | 518.924 | 518.968 | 0.044 | NVA |
| NVA1019 | 650692.635 | 4595439.694 | 449.732 | 449.761 | 0.029 | NVA |
| NVA1020 | 638514.944 | 4554941.969 | 493.589 | 493.639 | 0.05 | NVA |
| NVA1021 | 674476.761 | 4608801.671 | 462.968 | 463.027 | 0.059 | NVA |
| NVA1022 | 655777.794 | 4577744.069 | 437.078 | 437.045 | -0.033 | NVA |
| NVA1023 | 700419.816 | 4601368.132 | 401.049 | 401.03 | -0.019 | NVA |
| NVA1024 | 656572.954 | 4621061.342 | 453.064 | 453.053 | -0.011 | NVA |
| NVA1025 | 642421.609 | 4606567.054 | 480.605 | 480.582 | -0.023 | NVA |
| NVA1026 | 707505.443 | 4623083.144 | 390.137 | 390.113 | -0.024 | NVA |
| NVA1027 | 626002.586 | 4583196.41 | 455.648 | 455.68 | 0.032 | NVA |
| NVA1028 | 710327.219 | 4567242.158 | 368.001 | 367.913 | -0.088 | NVA |
| NVA1029 | 687689.61 | 4583357.009 | 413.938 | 413.938 | 0 | NVA |
| NVA1030 | 646586.404 | 4619074.314 | 512.861 | 512.809 | -0.052 | NVA |
| NVA1031 | 617052.814 | 4592334.328 | 464.308 | 464.314 | 0.006 | NVA |
| NVA1032 | 656866.397 | 4608434.47 | 482.022 | 482.051 | 0.029 | NVA |
| NVA1033 | 666869.786 | 4582879.539 | 427.35 | 427.332 | -0.018 | NVA |
| NVA1034 | 672810.637 | 4586743.167 | 407.018 | 407.054 | 0.036 | NVA |

| | | | | | | |
|---|---|---|---|---|---|---|
| NVA1035 | 662617.415 | 4590856.099 | 411.589 | 411.58 | -0.009 | NVA |
| NVA1036 | 697781.181 | 4548112.337 | 378.866 | 378.838 | -0.028 | NVA |
| NVA1037 | 699637.619 | 4564253.966 | 363.662 | 363.65 | -0.012 | NVA |
| NVA1038 | 685064.815 | 4592432.964 | 388.156 | 388.18 | 0.024 | NVA |
| NVA1039 | 598864.924 | 4612241.84 | 572.769 | 572.82 | 0.051 | NVA |
| NVA1040 | 619288.691 | 4615321.52 | 524.595 | 524.582 | -0.013 | NVA |
| NVA1041 | 662247.032 | 4573090.61 | 460.507 | 460.509 | 0.002 | NVA |
| NVA1042 | 665883.138 | 4621434.044 | 445.71 | 445.771 | 0.061 | NVA |
| NVA1043 | 650945.01 | 4548299.482 | 469.582 | 469.642 | 0.06 | NVA |
| NVA1044 | 670940.468 | 4572276.475 | 455.476 | 455.417 | -0.059 | NVA |
| NVA1045 | 719683.278 | 4546609.526 | 336.387 | 336.442 | 0.055 | NVA |
| NVA1047 | 699613.85 | 4585285.305 | 393.815 | 393.784 | -0.031 | NVA |
| NVA1048 | 653038.039 | 4553569.297 | 463.071 | 463.09 | 0.019 | NVA |
| NVA1049 | 688959.303 | 4562563.822 | 383.021 | 382.918 | -0.103 | NVA |
| NVA1050 | 656279.462 | 4568523.398 | 491.552 | 491.593 | 0.041 | NVA |
| NVA1051 | 599189.121 | 4599040.134 | 517.322 | 517.386 | 0.064 | NVA |
| NVA1052 | 627473.688 | 4617674.12 | 516.133 | 516.168 | 0.035 | NVA |
| NVA1053 | 608491.719 | 4616950.036 | 505.616 | 505.62 | 0.004 | NVA |
| NVA1054 | 721601.363 | 4589018.782 | 351.884 | 351.78 | -0.104 | NVA |
| NVA1055 | 634476.101 | 4593059.832 | 468.126 | 468.202 | 0.076 | NVA |
| NVA1056 | 711137.784 | 4601165.996 | 365.591 | 365.546 | -0.045 | NVA |
| NVA1057 | 690817.55 | 4570894.603 | 384.969 | 384.983 | 0.014 | NVA |
| NVA1058 | 708278.665 | 4548369.111 | 379.949 | 380.036 | 0.087 | NVA |
| VVA2001 | 707718.856 | 4564525.684 | 362.398 | 362.417 | 0.019 | VVA |
| VVA2002 | 643090.385 | 4587338.24 | 432.094 | 432.071 | -0.023 | VVA |
| VVA2003 | 678501.21 | 4565424.401 | 455.79 | 455.892 | 0.102 | VVA |
| VVA2004 | 706984.573 | 4620683.082 | 383.522 | 383.614 | 0.092 | VVA |
| VVA2005 | 675976.529 | 4608822.112 | 442.097 | 442.275 | 0.178 | VVA |
| VVA2005_ALT | 674512.388 | 4608775.242 | 464.495 | 464.611 | 0.116 | VVA |
| VVA2006 | 625476.953 | 4604676.685 | 482.091 | 482.141 | 0.05 | VVA |
| VVA2007 | 642401.02 | 4606530.417 | 478.203 | 478.241 | 0.038 | VVA |
| VVA2008 | 691990.975 | 4572183.746 | 412.207 | 412.363 | 0.156 | VVA |
| VVA2009 | 699162.585 | 4591619.831 | 374.27 | 374.231 | -0.039 | VVA |
| VVA2010 | 677257.182 | 4552374.387 | 444.014 | 444.085 | 0.071 | VVA |
| VVA2011 | 685223.567 | 4598169.03 | 388.732 | 388.611 | -0.121 | VVA |
| VVA2012 | 676664.833 | 4587023.113 | 433.485 | 433.554 | 0.069 | VVA |
| VVA2013 | 658209.281 | 4621162.357 | 470.798 | 470.964 | 0.166 | VVA |
| VVA2014 | 638565.983 | 4554991.894 | 493.435 | 493.443 | 0.008 | VVA |
| VVA2015 | 695785.941 | 4613782.17 | 378.737 | 378.739 | 0.002 | VVA |
| VVA2016 | 621832.191 | 4587485.957 | 460.767 | 460.741 | -0.026 | VVA |

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|---|---|---|---|---|---|---|
| VVA2017 | 646777.376 | 4546191.548 | 482.767 | 482.821 | 0.054 | VVA |
| VVA2018 | 686841.486 | 4554375.832 | 415.723 | 415.722 | -0.001 | VVA |
| VVA2019 | 649550.553 | 4568399.298 | 482.575 | 482.632 | 0.057 | VVA |
| VVA2020 | 683950.023 | 4618908.51 | 400.879 | 400.927 | 0.048 | VVA |
| VVA2021 | 688093.879 | 4583372.9 | 413.542 | 413.483 | -0.059 | VVA |
| VVA2022 | 706522.115 | 4607738.39 | 393.339 | 393.434 | 0.095 | VVA |
| VVA2023 | 716123.923 | 4554195.993 | 345.87 | 345.863 | -0.007 | VVA |
| VVA2024 | 599539.37 | 4598677.65 | 516.816 | 516.984 | 0.168 | VVA |
| VVA2025 | 627775.801 | 4619164.879 | 494.657 | 494.694 | 0.037 | VVA |
| VVA2026 | 664308.623 | 4573137.289 | 503.199 | 503.286 | 0.087 | VVA |
| VVA2027 | 632987.164 | 4593219.847 | 470.359 | 470.422 | 0.063 | VVA |
| VVA2028 | 657754.24 | 4608467.703 | 451.33 | 451.426 | 0.096 | VVA |
| VVA2029 | 665722.534 | 4562969.75 | 494.283 | 494.356 | 0.073 | VVA |
| VVA2030 | 656654.771 | 4577771.93 | 434.046 | 434.101 | 0.055 | VVA |
| VVA2031 | 700424.515 | 4601740.663 | 402.07 | 402.02 | -0.05 | VVA |
| VVA2032 | 718168.908 | 4568036.369 | 349.169 | 349.185 | 0.016 | VVA |
| VVA2033 | 713893.251 | 4576517.998 | 382.051 | 382.115 | 0.064 | VVA |
| VVA2034 | 721582.657 | 4589055.248 | 351.009 | 351.131 | 0.122 | VVA |
| VVA2035 | 653021.442 | 4553547.365 | 462.159 | 462.314 | 0.155 | VVA |
| VVA2035_alt | 653077.483 | 4552776.064 | 467.082 | 467.163 | 0.081 | VVA |
| VVA2036 | 612137.268 | 4592878.344 | 476.354 | 476.41 | 0.056 | VVA |
| VVA2037 | 605390.26 | 4605928.587 | 519.301 | 519.384 | 0.083 | VVA |
| VVA2038 | 649847.505 | 4595409.303 | 453.087 | 453.149 | 0.062 | VVA |
| VVA2039 | 636037.243 | 4603265.564 | 503.403 | 503.338 | -0.065 | VVA |
| VVA2040 | 697709.923 | 4547989.831 | 372.13 | 372.115 | -0.015 | VVA |
| VVA2041 | 619638.588 | 4617488.139 | 526.128 | 526.15 | 0.022 | VVA |
| NVA_extra_sew | 639079.775 | 4525946.874 | 482.766 | 482.766 | 0 | NVA |
| NVA_extra_york | 629267.843 | 4536958.309 | 477.792 | 477.77 | -0.022 | NVA |
| NVA1059 | 618677.11 | 4527599.376 | 505.907 | 505.95 | 0.043 | NVA |
| NVA1060 | 645491.174 | 4501725.87 | 472.842 | 472.854 | 0.012 | NVA |
| NVA1061 | 641161.407 | 4475370.394 | 488.405 | 488.421 | 0.016 | NVA |
| NVA1061_alt | 641052.216 | 4475488.965 | 489.01 | 488.993 | -0.017 | NVA |
| NVA1062 | 604455.643 | 4486718.482 | 512.486 | 512.505 | 0.019 | NVA |
| NVA1063 | 670106.571 | 4498565.621 | 419.995 | 419.951 | -0.044 | NVA |
| NVA1063_alt | 670096.552 | 4498603.777 | 418.953 | 418.972 | 0.019 | NVA |
| NVA1064 | 608173.057 | 4475448.226 | 503.433 | 503.446 | 0.013 | NVA |
| NVA1065 | 650234.241 | 4521377.953 | 471.124 | 471.162 | 0.038 | NVA |
| NVA1066 | 672097.821 | 4482572.429 | 423.226 | 423.209 | -0.017 | NVA |
| NVA1067 | 627679.987 | 4536919.151 | 477.238 | 477.251 | 0.013 | NVA |
| NVA1068 | 638882.306 | 4537234.569 | 477.352 | 477.354 | 0.002 | NVA |

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|---|---|---|---|---|---|---|
| NVA1069 | 628354.682 | 4495125.943 | 492.796 | 492.79 | -0.006 | NVA |
| NVA1070 | 620726.473 | 4474074.08 | 490.557 | 490.598 | 0.041 | NVA |
| NVA1071 | 675937.433 | 4507311.3 | 429.233 | 429.251 | 0.018 | NVA |
| NVA1072 | 624840.98 | 4513560.238 | 468.735 | 468.735 | 0 | NVA |
| NVA1073 | 676421.904 | 4473638.577 | 393.494 | 393.484 | -0.01 | NVA |
| NVA1073_alt | 676910.942 | 4473356.962 | 393.844 | 393.88 | 0.036 | NVA |
| NVA1074 | 634452.954 | 4515357.723 | 456.989 | 456.937 | -0.052 | NVA |
| NVA1075 | 608846.716 | 4498156.214 | 515.984 | 515.973 | -0.011 | NVA |
| NVA1076 | 662999.5 | 4471641.368 | 414.425 | 414.398 | -0.027 | NVA |
| NVA1077 | 636498.38 | 4484683.439 | 487.425 | 487.455 | 0.03 | NVA |
| NVA1078 | 652283.534 | 4505210.653 | 463.171 | 463.165 | -0.006 | NVA |
| NVA1079 | 619585.675 | 4487228.306 | 501.411 | 501.457 | 0.046 | NVA |
| NVA1080 | 618784.574 | 4511423.807 | 473.498 | 473.533 | 0.035 | NVA |
| NVA1081 | 605087.912 | 4539844.684 | 530.917 | 530.932 | 0.015 | NVA |
| NVA1082 | 650964.073 | 4490700.337 | 480.119 | 480.12 | 0.001 | NVA |
| NVA1083 | 674336.155 | 4517653.938 | 404.134 | 404.171 | 0.037 | NVA |
| NVA1084 | 661425.414 | 4532538.083 | 444.933 | 444.979 | 0.046 | NVA |
| NVA1085 | 605658.31 | 4526504.486 | 522.96 | 523.025 | 0.065 | NVA |
| NVA1086 | 599895.821 | 4514750.441 | 524.499 | 524.483 | -0.016 | NVA |
| NVA1087 | 667989.874 | 4528088.673 | 472.743 | 472.786 | 0.043 | NVA |
| NVA1088 | 619275.177 | 4499281.438 | 500.448 | 500.49 | 0.042 | NVA |
| NVA1089 | 660473.284 | 4494066.35 | 437.866 | 437.828 | -0.038 | NVA |
| NVA1090 | 639319.146 | 4528201.568 | 483.175 | 483.217 | 0.042 | NVA |
| NVA1091 | 653056.191 | 4472676.073 | 454.237 | 454.281 | 0.044 | NVA |
| NVA1092 | 631288.014 | 4500935.085 | 489.858 | 489.848 | -0.01 | NVA |
| NVA1093 | 626314.28 | 4522413.97 | 475.917 | 475.919 | 0.002 | NVA |
| NVA1094 | 617331.653 | 4540378.984 | 514.909 | 514.95 | 0.041 | NVA |
| NVA1095 | 631225.776 | 4475038.773 | 484.583 | 484.558 | -0.025 | NVA |
| NVA1095_alt | 631229.541 | 4475024.468 | 484.346 | 484.312 | -0.034 | NVA |
| NVA1096 | 634121.785 | 4543030.168 | 493.495 | 493.477 | -0.018 | NVA |
| NVA1097 | 601414.393 | 4472180.266 | 509.616 | 509.577 | -0.039 | NVA |
| NVA1098 | 653834.051 | 4537517.186 | 451.155 | 451.161 | 0.006 | NVA |
| NVA1099 | 645183.837 | 4515202.135 | 443.109 | 443.15 | 0.041 | NVA |
| NVA1100 | 664789.432 | 4515118.626 | 435.216 | 435.257 | 0.041 | NVA |
| NVA1101 | 610188.314 | 4519965.254 | 516.275 | 516.316 | 0.041 | NVA |
| NVA1102 | 674121.187 | 4540276.737 | 424.592 | 424.624 | 0.032 | NVA |
| VVA2042 | 644102.68 | 4514673.264 | 444.761 | 444.922 | 0.161 | VVA |
| VVA2043 | 622066.486 | 4486937.573 | 496.205 | 496.262 | 0.057 | VVA |
| VVA2044 | 598964.89 | 4526885.848 | 528.916 | 528.93 | 0.014 | VVA |
| VVA2045 | 666057.336 | 4545468.404 | 475.097 | 475.223 | 0.126 | VVA |

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|---|---|---|---|---|---|---|
| VVA2046 | 667424.636 | 4500680.744 | 440.485 | 440.556 | 0.071 | VVA |
| VVA2047 | 658312.331 | 4529379.248 | 438.492 | 438.629 | 0.137 | VVA |
| VVA2048 | 649778.755 | 4476142.205 | 473.801 | 473.753 | -0.048 | VVA |
| VVA2049 | 632333.709 | 4543265.377 | 486.411 | 486.455 | 0.044 | VVA |
| VVA2050 | 640583.131 | 4526823.609 | 481.593 | 481.735 | 0.142 | VVA |
| VVA2051 | 668819.747 | 4487753.061 | 414.619 | 414.622 | 0.003 | VVA |
| VVA2052 | 629770.395 | 4504882.474 | 484.666 | 484.759 | 0.093 | VVA |
| VVA2053 | 668501.091 | 4528104.808 | 464.728 | 464.776 | 0.048 | VVA |
| VVA2054 | 604525.415 | 4485785.857 | 510.553 | 510.607 | 0.054 | VVA |
| VVA2055 | 628384.718 | 4494387.653 | 491.928 | 492.062 | 0.134 | VVA |
| VVA2056 | 672560.552 | 4476603.788 | 414.551 | 414.531 | -0.02 | VVA |
| VVA2057 | 620722.07 | 4474058.19 | 490.309 | 490.391 | 0.082 | VVA |
| VVA2058 | 648480.679 | 4536923.734 | 455.421 | 455.458 | 0.037 | VVA |
| VVA2059 | 613987.043 | 4499532.984 | 502.233 | 502.29 | 0.057 | VVA |
| VVA2060 | 652064.498 | 4521337.299 | 469.336 | 469.351 | 0.015 | VVA |
| VVA2061 | 665846.455 | 4470632.339 | 418.34 | 418.335 | -0.005 | VVA |
| VVA2062 | 637980.038 | 4500581.135 | 475.795 | 475.818 | 0.023 | VVA |
| VVA2063 | 630271.704 | 4479106.437 | 481.504 | 481.538 | 0.034 | VVA |
| VVA2063_alt | 630326.637 | 4479649.325 | 479.473 | 479.511 | 0.038 | VVA |
| VVA2064 | 605130.077 | 4538267.631 | 532.524 | 532.539 | 0.015 | VVA |
| VVA2065 | 618557.435 | 4527984.797 | 504.75 | 504.845 | 0.095 | VVA |
| VVA2066 | 609414.07 | 4475229.397 | 500.561 | 500.585 | 0.024 | VVA |
| VVA2067 | 652280.309 | 4504784.963 | 455.339 | 455.375 | 0.036 | VVA |
| VVA2068 | 602539.372 | 4499531.191 | 509.508 | 509.569 | 0.061 | VVA |
| VVA2069 | 601410.676 | 4470590.025 | 509.383 | 509.364 | -0.019 | VVA |
| VVA2070 | 675459.179 | 4507321.423 | 442.985 | 443.007 | 0.022 | VVA |
| VVA2071 | 638845.199 | 4537200.772 | 476.681 | 476.737 | 0.056 | VVA |
| VVA2072 | 605467.215 | 4517283.457 | 514.666 | 514.778 | 0.112 | VVA |
| NVA1103 | 387653.576 | 4478820.572 | 780.153 | 780.128 | -0.025 | NVA |
| NVA1105 | 376854.296 | 4501794.959 | 828.488 | 828.478 | -0.01 | NVA |
| NVA1115 | 412020.052 | 4483401.606 | 759.749 | 759.771 | 0.022 | NVA |
| NVA1116 | 360212.67 | 4480857.38 | 853.838 | 853.826 | -0.012 | NVA |
| NVA1118 | 368487.87 | 4494027.604 | 853.155 | 853.128 | -0.027 | NVA |
| NVA1119 | 406254.568 | 4472146.176 | 723.04 | 723.012 | -0.028 | NVA |
| NVA1124 | 379565.455 | 4486343.926 | 801.64 | 801.623 | -0.017 | NVA |
| NVA1130 | 388865.624 | 4498699.494 | 836.548 | 836.577 | 0.029 | NVA |
| NVA1131 | 355445.784 | 4485848.76 | 879.289 | 879.284 | -0.005 | NVA |
| NVA1135 | 408660.485 | 4506011.314 | 835.961 | 835.988 | 0.027 | NVA |
| NVA1137 | 399092.439 | 4481983.674 | 775.499 | 775.538 | 0.039 | NVA |
| NVA1151 | 371379.298 | 4472539.171 | 826.773 | 826.768 | -0.005 | NVA |

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|---|---|---|---|---|---|---|
| NVA1156 | 395190.666 | 4491788.125 | 805.509 | 805.523 | 0.014 | NVA |
| NVA1160 | 406443.723 | 4491441.272 | 778.081 | 778.087 | 0.006 | NVA |
| NVA1161 | 379224.01 | 4467646.649 | 805.281 | 805.265 | -0.016 | NVA |
| NVA1164 | 355634.03 | 4497236.369 | 887.751 | 887.724 | -0.027 | NVA |
| NVA1167 | 399273.377 | 4504578.826 | 860.908 | 860.888 | -0.02 | NVA |
| NVA1168 | 352072.798 | 4473783.681 | 839.828 | 839.84 | 0.012 | NVA |
| NVA1104 | 409615.067 | 4459221.215 | 680.42 | 680.398 | -0.022 | NVA |
| NVA1109 | 417733.267 | 4463909.187 | 674.382 | 674.382 | 0 | NVA |
| NVA1112 | 427133.543 | 4437947.604 | 695.44 | 695.38 | -0.06 | NVA |
| NVA1121 | 422427.116 | 4452513.194 | 722.864 | 722.783 | -0.081 | NVA |
| NVA1122 | 436742.604 | 4443664.074 | 640.772 | 640.789 | 0.017 | NVA |
| NVA1123 | 417517.226 | 4434838.192 | 718.307 | 718.339 | 0.032 | NVA |
| NVA1128 | 402999.806 | 4433359.115 | 765.129 | 765.071 | -0.058 | NVA |
| NVA1139 | 445591.989 | 4449896.236 | 682.487 | 682.47 | -0.017 | NVA |
| NVA1142 | 411236.704 | 4444623.692 | 730.875 | 730.897 | 0.022 | NVA |
| NVA1144 | 432055.405 | 4462279.529 | 672.657 | 672.649 | -0.008 | NVA |
| NVA1145 | 437482.694 | 4431474.564 | 671.186 | 671.199 | 0.013 | NVA |
| NVA1152 | 441563.269 | 4458850.36 | 661.04 | 661.053 | 0.013 | NVA |
| NVA1162 | 445722.208 | 4429752.227 | 689.912 | 689.912 | 0 | NVA |
| NVA1106 | 426870.151 | 4493314.473 | 815.693 | 815.678 | -0.015 | NVA |
| NVA1133 | 427576.485 | 4481574.588 | 749.683 | 749.733 | 0.05 | NVA |
| NVA1134 | 420221.502 | 4504249.914 | 789.189 | 789.168 | -0.021 | NVA |
| NVA1140 | 428105.34 | 4493338.708 | 805.652 | 805.666 | 0.014 | NVA |
| NVA1143 | 432733.061 | 4470245.067 | 713.568 | 713.578 | 0.01 | NVA |
| NVA1146 | 416782.441 | 4476869.229 | 726.207 | 726.181 | -0.026 | NVA |
| NVA1148 | 445394.566 | 4471754.066 | 718.841 | 718.89 | 0.049 | NVA |
| NVA1150 | 437622.437 | 4499243.806 | 760.705 | 760.72 | 0.015 | NVA |
| NVA1153 | 439186.691 | 4486336.084 | 779.453 | 779.474 | 0.021 | NVA |
| NVA1157 | 444958.019 | 4494308.063 | 754.604 | 754.614 | 0.01 | NVA |
| NVA1107 | 336047.088 | 4501154.605 | 881.241 | 881.214 | -0.027 | NVA |
| NVA1129 | 344721.96 | 4503808.48 | 934.085 | 934.145 | 0.06 | NVA |
| NVA1110 | 371925.291 | 4524894.489 | 863.728 | 863.686 | -0.042 | NVA |
| NVA1117 | 380258.778 | 4517013.934 | 925.239 | 925.234 | -0.005 | NVA |
| NVA1125 | 345802.844 | 4526252.284 | 918.092 | 918.07 | -0.022 | NVA |
| NVA1132 | 371503.9 | 4511351.637 | 865.235 | 865.239 | 0.004 | NVA |
| NVA1136 | 356814.657 | 4507394.409 | 905.304 | 905.303 | -0.001 | NVA |
| NVA1149 | 347587.784 | 4511823.078 | 924.764 | 924.745 | -0.019 | NVA |
| NVA1159 | 352473.042 | 4539031.509 | 937.727 | 937.745 | 0.018 | NVA |
| NVA1163 | 358578.128 | 4526021.355 | 919.589 | 919.601 | 0.012 | NVA |
| NVA1165 | 358900.338 | 4538880.833 | 905.981 | 906.031 | 0.05 | NVA |

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|---|---|---|---|---|---|---|
| NVA1108 | 399565.955 | 4456014.453 | 703.831 | 703.796 | -0.035 | NVA |
| NVA1111 | 390263.679 | 4462489.981 | 757.577 | 757.569 | -0.008 | NVA |
| NVA1113 | 352556.594 | 4443142.318 | 791.834 | 791.846 | 0.012 | NVA |
| NVA1114 | 396702.915 | 4443123.664 | 768.374 | 768.388 | 0.014 | NVA |
| NVA1120 | 372714.715 | 4459673.129 | 780.808 | 780.778 | -0.03 | NVA |
| NVA1126 | 382204.14 | 4441725.499 | 811.113 | 811.132 | 0.019 | NVA |
| NVA1127 | 388603.998 | 4431906.648 | 768.216 | 768.199 | -0.017 | NVA |
| NVA1138 | 361967.509 | 4447898.817 | 757.945 | 757.953 | 0.008 | NVA |
| NVA1141 | 372633.317 | 4450096.733 | 762.852 | 762.803 | -0.049 | NVA |
| NVA1147 | 351763.886 | 4462352.944 | 834.382 | 834.346 | -0.036 | NVA |
| NVA1154 | 359832.636 | 4462737.644 | 829.463 | 829.439 | -0.024 | NVA |
| NVA1155 | 365894.711 | 4430229.59 | 808.224 | 808.215 | -0.009 | NVA |
| NVA1158 | 353099.655 | 4432248.465 | 890.844 | 890.882 | 0.038 | NVA |
| NVA1166 | 382931.042 | 4453485.252 | 724.326 | 724.256 | -0.07 | NVA |
| VVA2073 | 357459.527 | 4506756.552 | 891.616 | 891.661 | 0.045 | VVA |
| VVA2075 | 387671.377 | 4478833.775 | 780.681 | 780.665 | -0.016 | VVA |
| VVA2080 | 388851.105 | 4499068.116 | 840.343 | 840.361 | 0.018 | VVA |
| VVA2083 | 376243.823 | 4485565.817 | 832.936 | 832.956 | 0.02 | VVA |
| VVA2092 | 376777.475 | 4500038.713 | 814.007 | 814.063 | 0.056 | VVA |
| VVA2099 | 406432.438 | 4491415.73 | 777.552 | 777.627 | 0.075 | VVA |
| VVA2102 | 399252.088 | 4504542.838 | 860.257 | 860.319 | 0.062 | VVA |
| VVA2106 | 351584.652 | 4472931.477 | 834.313 | 834.329 | 0.016 | VVA |
| VVA2113 | 355461.451 | 4484634.607 | 879.767 | 879.812 | 0.045 | VVA |
| VVA2116 | 355812.381 | 4496440.75 | 881.946 | 882.029 | 0.083 | VVA |
| VVA2084 | 426634.473 | 4493325.622 | 817.955 | 817.998 | 0.043 | VVA |
| VVA2089 | 431061.319 | 4470229.778 | 693.66 | 693.727 | 0.067 | VVA |
| VVA2096 | 416798.778 | 4475718.366 | 706.111 | 706.178 | 0.067 | VVA |
| VVA2098 | 444011.02 | 4494015.307 | 755.424 | 755.474 | 0.05 | VVA |
| VVA2117 | 437567.357 | 4498389.025 | 759.094 | 759.156 | 0.062 | VVA |
| VVA2118 | 439135.442 | 4486348.42 | 778.182 | 778.271 | 0.089 | VVA |
| VVA2103 | 336089.38 | 4501042.206 | 880.793 | 880.805 | 0.012 | VVA |
| VVA2108 | 344746.579 | 4503833.077 | 932.915 | 933.089 | 0.174 | VVA |
| VVA2076 | 352371.042 | 4537378.242 | 934.518 | 934.603 | 0.085 | VVA |
| VVA2078 | 345829.334 | 4526219.831 | 917.941 | 917.988 | 0.047 | VVA |
| VVA2085 | 357034.464 | 4526070.917 | 913.989 | 914.04 | 0.051 | VVA |
| VVA2088 | 347647.068 | 4511831.928 | 923.506 | 923.509 | 0.003 | VVA |
| VVA2093 | 380314.779 | 4517022.835 | 926.533 | 926.519 | -0.014 | VVA |
| VVA2110 | 357237.255 | 4538895.93 | 916.656 | 916.783 | 0.127 | VVA |
| VVA2112 | 371461.791 | 4511360.566 | 864.776 | 864.779 | 0.003 | VVA |
| VVA2077 | 382960.045 | 4453451.837 | 725.729 | 725.828 | 0.099 | VVA |

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|---|---|---|---|---|---|---|
| VVA2081 | 399727.09 | 4455973.464 | 703.312 | 703.345 | 0.033 | VVA |
| VVA2082 | 360058.354 | 4462732.818 | 827.61 | 827.605 | -0.005 | VVA |
| VVA2094 | 396690.076 | 4444132.337 | 766.321 | 766.473 | 0.152 | VVA |
| VVA2095 | 352290.721 | 4431531.207 | 880.874 | 880.941 | 0.067 | VVA |
| VVA2097 | 382218.586 | 4441712.641 | 810.497 | 810.562 | 0.065 | VVA |
| VVA2101 | 373960.045 | 4450055.609 | 763.035 | 763.064 | 0.029 | VVA |
| VVA2104 | 379239.891 | 4466062.482 | 806.247 | 806.275 | 0.028 | VVA |
| VVA2105 | 361117.076 | 4446223.393 | 766.898 | 766.996 | 0.098 | VVA |
| VVA2107 | 351751.851 | 4462352.539 | 832.787 | 832.89 | 0.103 | VVA |
| VVA2109 | 387073.259 | 4431911.815 | 763.217 | 763.284 | 0.067 | VVA |
| VVA2111 | 390247.446 | 4461174.704 | 739.957 | 740.038 | 0.081 | VVA |
| VVA2074 | 427081.88 | 4438002.61 | 692.001 | 692.001 | 0 | VVA |
| VVA2079 | 422378.851 | 4453064.015 | 718.648 | 718.647 | -0.001 | VVA |
| VVA2086 | 432016.575 | 4462033.783 | 675.577 | 675.647 | 0.07 | VVA |
| VVA2087 | 409060.707 | 4459172.837 | 681.319 | 681.293 | -0.026 | VVA |
| VVA2090 | 402939.44 | 4432984.817 | 753.893 | 753.906 | 0.013 | VVA |
| VVA2091 | 444769.068 | 4449050.435 | 669.351 | 669.425 | 0.074 | VVA |
| VVA2091_alt | 444731.777 | 4449036.086 | 671.587 | 671.64 | 0.053 | VVA |
| VVA2100 | 436692.76 | 4443552.901 | 641.825 | 641.871 | 0.046 | VVA |
| VVA2114 | 416558.713 | 4434849.709 | 718.83 | 718.891 | 0.061 | VVA |
| VVA2115 | 417723.748 | 4465187.63 | 704.007 | 704.099 | 0.092 | VVA |
| NVA1169 | 780325.6716 | 4449114.779 | 292.546 | 292.611 | 0.065 | NVA |
| NVA1171 | 774505.2884 | 4458261.721 | 307.809 | 307.821 | 0.012 | NVA |
| NVA1173 | 772874.6049 | 4433201.483 | 340.284 | 340.302 | 0.018 | NVA |
| NVA1179 | 765341.6574 | 4490414.251 | 311.345 | 311.344 | -0.001 | NVA |
| NVA1179_alt | 765332.7137 | 4490418.378 | 310.973 | 310.974 | 0.001 | NVA |
| NVA1180 | 754596.8635 | 4477793.553 | 376.888 | 376.862 | -0.026 | NVA |
| NVA1181 | 802990.5265 | 4446640.348 | 273.407 | 273.467 | 0.06 | NVA |
| NVA1182 | 790902.8856 | 4441917.481 | 300.447 | 300.462 | 0.015 | NVA |
| NVA1182_alt | 790903.277 | 4441981.458 | 299.742 | 299.787 | 0.045 | NVA |
| NVA1183 | 782179.0801 | 4459447.419 | 343.877 | 343.873 | -0.004 | NVA |
| NVA1183_alt | 782178.3548 | 4459464.731 | 343.449 | 343.439 | -0.01 | NVA |
| NVA1185 | 758146.123 | 4438393.215 | 313.532 | 313.549 | 0.017 | NVA |
| NVA1189 | 791181.1231 | 4457584.823 | 339.596 | 339.64 | 0.044 | NVA |
| NVA1191 | 762568.3666 | 4498447.432 | 331.612 | 331.618 | 0.006 | NVA |
| NVA1192 | 765393.4466 | 4461433.62 | 330.157 | 330.156 | -0.001 | NVA |
| NVA1194 | 760336.0144 | 4469242.445 | 323.844 | 323.82 | -0.024 | NVA |
| NVA1197 | 764688.5107 | 4508977.431 | 309.822 | 309.802 | -0.02 | NVA |
| NVA1202 | 786793.6829 | 4447735.187 | 300.915 | 300.911 | -0.004 | NVA |
| NVA1206 | 786617.1461 | 4436431.72 | 293.629 | 293.649 | 0.02 | NVA |

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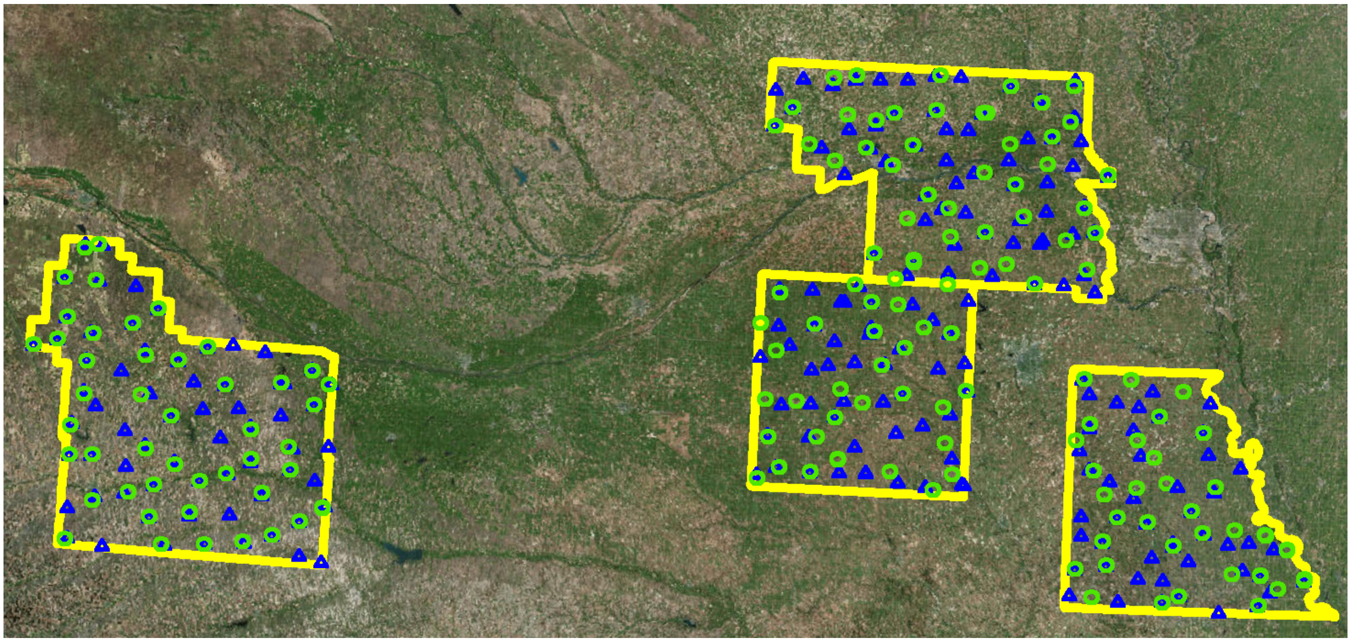
|---|---|---|---|---|---|---|
| NVA1207 | 768292.2629 | 4476817.6 | 283.493 | 283.508 | 0.015 | NVA |
| NVA1210 | 760534.8859 | 4451314.739 | 320.037 | 320.032 | -0.005 | NVA |
| NVA1213 | 777147.6899 | 4486241.953 | 289.492 | 289.497 | 0.005 | NVA |
| NVA1213_alt | 777289.2667 | 4486209.799 | 286.816 | 286.821 | 0.005 | NVA |
| VVA2119 | 762612.5119 | 4498036.221 | 335.166 | 335.182 | 0.016 | VVA |
| VVA2122 | 764884.7207 | 4461445.226 | 337.443 | 337.541 | 0.098 | VVA |
| VVA2123 | 754467.772 | 4512482.395 | 365.916 | 365.996 | 0.08 | VVA |
| VVA2125 | 793424.0519 | 4443193.143 | 285.256 | 285.292 | 0.036 | VVA |
| VVA2127 | 776336.6301 | 4447372.829 | 303.488 | 303.488 | 0 | VVA |
| VVA2128 | 776454.606 | 4463521.413 | 319.475 | 319.492 | 0.017 | VVA |
| VVA2128_alt | 776409.4004 | 4463515.957 | 321.174 | 321.195 | 0.021 | VVA |
| VVA2131 | 787021.2688 | 4436494.46 | 281.334 | 281.391 | 0.057 | VVA |
| VVA2132 | 757823.7184 | 4438090.136 | 323.174 | 323.194 | 0.02 | VVA |
| VVA2137 | 786786.0352 | 4447748.561 | 301.492 | 301.513 | 0.021 | VVA |
| VVA2137_alt | 786829.6155 | 4447392.439 | 289.154 | 289.211 | 0.057 | VVA |
| VVA2140 | 802993.3959 | 4446656.408 | 272.336 | 272.43 | 0.094 | VVA |
| VVA2140_alt | 802925.2709 | 4447477.343 | 297.045 | 297.107 | 0.062 | VVA |
| VVA2143 | 787572.3724 | 4462293.244 | 336.826 | 336.876 | 0.05 | VVA |
| VVA2143_alt | 787783.7669 | 4462283.785 | 336.395 | 336.433 | 0.038 | VVA |
| VVA2145 | 768325.6118 | 4478564.52 | 281.035 | 281.041 | 0.006 | VVA |
| VVA2146 | 760286.5581 | 4469268.599 | 325.795 | 325.833 | 0.038 | VVA |
| VVA2150 | 796034.0073 | 4457188.205 | 315.698 | 315.734 | 0.036 | VVA |
| VVA2150_alt | 795832.916 | 4457646.687 | 335.494 | 335.545 | 0.051 | VVA |
| NVA1170 | 717323.751 | 4514710.396 | 383.583 | 383.539 | -0.044 | NVA |
| NVA1170_alt | 717318.573 | 4514643.874 | 387.555 | 387.548 | -0.007 | NVA |
| NVA1172 | 735758.441 | 4434728.19 | 387.202 | 387.198 | -0.004 | NVA |
| NVA1174 | 743124.945 | 4512128.943 | 351.111 | 351.043 | -0.068 | NVA |
| NVA1175 | 738950.861 | 4472734.895 | 353.861 | 353.918 | 0.057 | NVA |
| NVA1176 | 754370.987 | 4457355.884 | 364.602 | 364.6 | -0.002 | NVA |
| NVA1176_alt | 754420.213 | 4456243.98 | 345.89 | 345.888 | -0.002 | NVA |
| NVA1177 | 728746.588 | 4455919.598 | 398.02 | 397.961 | -0.059 | NVA |
| NVA1178 | 719274.509 | 4445567.339 | 424.768 | 424.736 | -0.032 | NVA |
| NVA1184 | 742563.95 | 4443553.516 | 361.148 | 361.12 | -0.028 | NVA |
| NVA1186 | 720280.878 | 4464935.676 | 423.522 | 423.533 | 0.011 | NVA |
| NVA1187 | 737072.914 | 4497633.406 | 347.218 | 347.2 | -0.018 | NVA |
| NVA1188 | 718062.388 | 4488772.013 | 398.942 | 398.938 | -0.004 | NVA |
| NVA1190 | 730530.447 | 4507277.679 | 349.268 | 349.211 | -0.057 | NVA |
| NVA1190_alt | 730512.642 | 4507258.94 | 349.244 | 349.205 | -0.039 | NVA |
| NVA1193 | 720848.877 | 4457958.966 | 446.869 | 446.887 | 0.018 | NVA |
| NVA1193_alt | 720844.834 | 4457931.275 | 446.961 | 446.968 | 0.007 | NVA |

| | | | | | | |
|---|---|---|---|---|---|---|
| NVA1195 | 721053.177 | 4497076.614 | 385.094 | 385.124 | 0.03 | NVA |
| NVA1196 | 730509.587 | 4447495.428 | 398.298 | 398.333 | 0.035 | NVA |
| NVA1198 | 717967.385 | 4435834.763 | 434.582 | 434.548 | -0.034 | NVA |
| NVA1199 | 738533.271 | 4505997.264 | 347.619 | 347.627 | 0.008 | NVA |
| NVA1200 | 729874.733 | 4478445.466 | 352.069 | 352.104 | 0.035 | NVA |
| NVA1201 | 722375.3 | 4482010.598 | 361.217 | 361.277 | 0.06 | NVA |
| NVA1203 | 740551.265 | 4488225.585 | 326.769 | 326.775 | 0.006 | NVA |
| NVA1204 | 744339.61 | 4463700.969 | 346.804 | 346.771 | -0.033 | NVA |
| NVA1205 | 720322.636 | 4509364.124 | 366.037 | 365.977 | -0.06 | NVA |
| NVA1208 | 746996.011 | 4451573.435 | 328.884 | 328.906 | 0.022 | NVA |
| NVA1209 | 746343.377 | 4502792.843 | 367.725 | 367.762 | 0.037 | NVA |
| NVA1211 | 751545.731 | 4443722.493 | 366.233 | 366.225 | -0.008 | NVA |
| NVA1212 | 751730.908 | 4435765.728 | 327.854 | 327.886 | 0.032 | NVA |
| NVA1212_alt | 751651.196 | 4435784.285 | 327.083 | 327.07 | -0.013 | NVA |
| NVA1214 | 733275.211 | 4465290.064 | 401.652 | 401.657 | 0.005 | NVA |
| VVA2120 | 750701.566 | 4478740.715 | 357.025 | 357.086 | 0.061 | VVA |
| VVA2121 | 726082.505 | 4435580.512 | 449.7 | 449.714 | 0.014 | VVA |
| VVA2124 | 739811.279 | 4476375.096 | 394.604 | 394.682 | 0.078 | VVA |
| VVA2126 | 754446.799 | 4456270.368 | 345.54 | 345.568 | 0.028 | VVA |
| VVA2129_rec | 718125.348 | 4514738.958 | 395.584 | 395.572 | -0.012 | VVA |
| VVA2130 | 738813.298 | 4493781.585 | 316.534 | 316.584 | 0.05 | VVA |
| VVA2133 | 730534.176 | 4447411.305 | 395.833 | 395.863 | 0.03 | VVA |
| VVA2134 | 720989.701 | 4498480.698 | 379.633 | 379.663 | 0.03 | VVA |
| VVA2135 | 728170.425 | 4473206.904 | 373.893 | 373.867 | -0.026 | VVA |
| VVA2136 | 751857.536 | 4435143.885 | 312.967 | 313.014 | 0.047 | VVA |
| VVA2138 | 728754.148 | 4456247.133 | 405.958 | 405.944 | -0.014 | VVA |
| VVA2139 | 723441.166 | 4481683.981 | 357.532 | 357.556 | 0.024 | VVA |
| VVA2141 | 733257.332 | 4465138.227 | 404.377 | 404.361 | -0.016 | VVA |
| VVA2142 | 734968.234 | 4515335.653 | 394.277 | 394.304 | 0.027 | VVA |
| VVA2144 | 745312.596 | 4487786.103 | 329.893 | 329.862 | -0.031 | VVA |
| VVA2147 | 746364.21 | 4502796.922 | 365.506 | 365.574 | 0.068 | VVA |
| VVA2148 | 716348.816 | 4492177.839 | 427 | 427.04 | 0.04 | VVA |
| VVA2149 | 719292.643 | 4445542.849 | 425.219 | 425.225 | 0.006 | VVA |
| VVA2151 | 744550.822 | 4464089.01 | 345.456 | 345.489 | 0.033 | VVA |

**Checkpoint Layout**

NVA
VVA



## Hydro-flattening Breakline Collection

Hydro- flattening breaklines are captured per the USGS National Geospatial Program Lidar Base Specification Version 1.2. Final hydro-flattened breaklines features are appropriately turned into polygons (flat elevations) and polylines (decreasing by elevation) and are used to reclassify ground points in water to Water (Class 9). The lidar points around the breaklines are reclassified to Ignored Ground (Class 10) based on predetermined buffer.

**Linear hydrographic features**

To collect hydrographic features, Merrick-Surdex JV uses a methodology that directly interacts with the lidar bare-earth data to collect drainage breaklines. To determine the alignment of a drainageway, the technician first views the area as a TIN of bare-earth points using a color ramp to depict varying elevations. In areas of extremely flat terrain, the technician may need to determine the direction of flow based on measuring lidar bare-earth points at each end of the drain. The operator will then use the color ramped TIN to digitize the drainage in 2D with the elevation being attributed directly from the bare-earth LAS data. MARS® software has the capability of “flipping” views between the elevation TIN, Intensity and imagery, as necessary, to further assist in the determination of the drainage. All drainage breaklines are collected in a downhill direction. For each point collected, the software uses a five-foot (5’) search radius to identify the lowest point within that proximity. Within each radius, if a bare-earth point is not found that is lower than the previous point, the elevation for subsequent point remains the same as the previous point. This forces the drain to always flow in a downhill direction. Waterbodies that are embedded along a drainageway are validated to ensure consistency with the downhill direction of flow.

This methodology may differ from those of other vendors in that Merrick-Surdex JV relies on the bare-earth data to attribute breakline elevations. As a result of our methodology, there is no mismatch between lidar bare-earth data and breaklines that might otherwise be collected in stereo 3D as a separate process. This is particularly important in densely vegetated areas where breaklines collected in 3D from imagery will most likely not match (either horizontally or vertically), the more reliable lidar bare-earth data.

Merrick-Surdex JV has the capability of “draping” 2D breaklines to a bare-earth elevation model to attribute the “z” as opposed to the forced downhill attribution methodology described above. However, the problem with this process is the “pooling “effect or depressions along the drainageway caused by a lack of consistent penetration in densely vegetated areas.

Criteria of linear hydrographic breaklines are as follows:

- Linear hydrographic features (e.g., visible streams, rivers, shorelines, canals, etc.) greater than one hundred feet (100’) wide will be captured as a double-lined polygon
    - linear hydrographic features must be flat and level bank-to-bank (perpendicular to the apparent flow centerline) with gradient following the immediately surrounding terrain
    - water surface edge must be at or just below the immediately surrounding terrain
    - streams should break at road crossings (e.g., culverts), and streams and rivers should not break at bridges

**Waterbodies**

Waterbodies are digitized from the color ramped TIN, similar to the process described above. The elevation attribute is determined as the technician collects the hydro feature by using the lowest bare-earth point within the polygon.

Criteria of waterbody breaklines are as follows:

- Waterbodies (e.g., lakes, ponds, reservoirs) greater than two (2) acres in size are surrounded by a water breakline (i.e., closed polygon)
    - waterbodies must be flat and level with a single elevation for every bank vertex
    - water surface edge must be at or just below the immediately surrounding terrain
    - long impoundments, such as reservoirs or inlets, whose water surface elevations drop when moving downstream should be treated as rivers

Color cycles provide a clear indication of where breaklines are to be collected, especially hydrographic breaklines. Figure 3 demonstrates no breaklines, where Figure 4 is breakline enforced displayed using color cycles within the MARS® software environment.

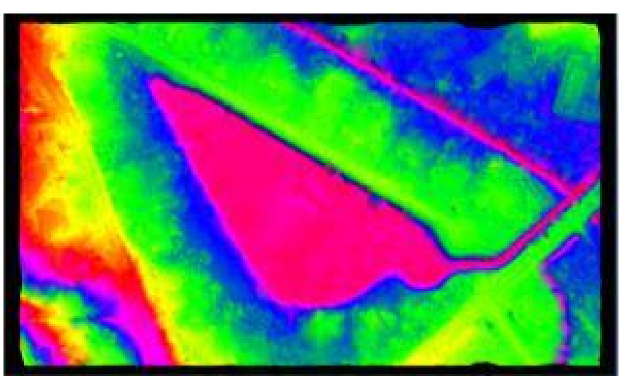


**Figure 3**

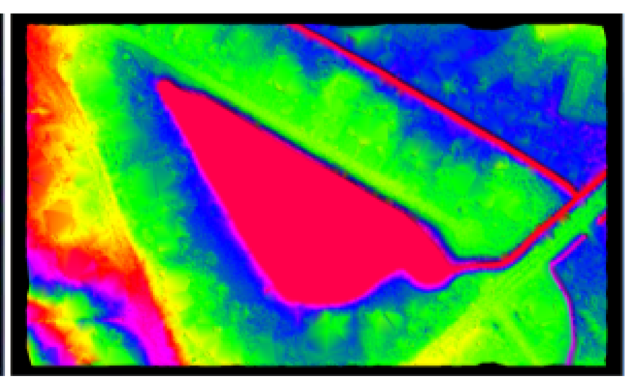


**Figure 4**

## Contour Generation

Contours are generated using MARS® proprietary software at the desired contour interval in which the lidar will accurately support. Topology QC checks are completed to ensure topography is logical and complete. Additional QC checks for dangles and appropriate attribution are also verified to comply with project requirements before delivery to the client.

## List of Deliverables

**Classified lidar point cloud**

- Fully compliant ASPRS LAS 1.4, point record format 6
- By tile
- Intensity values normalized (rescaled) to 16-bit
- FGDC-compliant metadata

**Bare-earth DEM**

- 1m cell size 32-bit floating point raster in ERDAS IMG format
- Bare-earth (hydro-flattened)
    - Culverts not be removed from the DEMs
    - Bridges removed from the DEMs
- By tile
- FGDC-compliant metadata

**First Return Digital Surface Model (DSM)**

- 1m cell size 32-bit floating point raster in ERDAS IMG format
- By tile and by county
- FGDC-compliant metadata

**Hillshades**

- 1m cell size in ERDAS IMG format
- By county
- FGDC-compliant metadata

**Hydro-flattened breaklines**

- Project-wide Esri feature class(es) for insertion into file geodatabase
    - PolylineZ
    - PolygonZ
- FGDC-compliant metadata

**Intensity Images**

- 1m cell size 8-bit, 256 color gray scale in GeoTIFF format
- By tile
- FGDC-compliant metadata

**Two-foot (2') contours**

- Esri feature class(es) for insertion into file geodatabase
- By county

- FGDC-compliant metadata

**Control**

- Survey report
- Esri shapefile format
- FGDC-compliant metadata

**FGDC-compliant metadata (project level)**

**Detailed Lidar Mapping / Project Report**

**4-Band Ortho Imagery**

- DOQQ-formatted 60cm pixel resolution 4-band (R,G,B,NIR) 32-bit (8-bit per band) orthoimagery in GeoTIFF format
- DOQQ tile index in Esri shapefile format
- Imagery (mosaic) seamlines in Esri shapefile format
- Compressed 4-band (R,G,B,NIR) CCM orthoimagery in MrSID format using a 60:1 compression ratio
- FGDC-compliant metadata
- Imagery Project Report detailing acquisition, processing and accuracy assessment

## Appendix 1

**Following is a more detailed lidar calibration workflow description.**

**LIDAR CALIBRATION AND BLOCK LAS OUTPUT**

Note: All figures represented on the following pages are for general illustration purposes, and are not examples derived from the project.

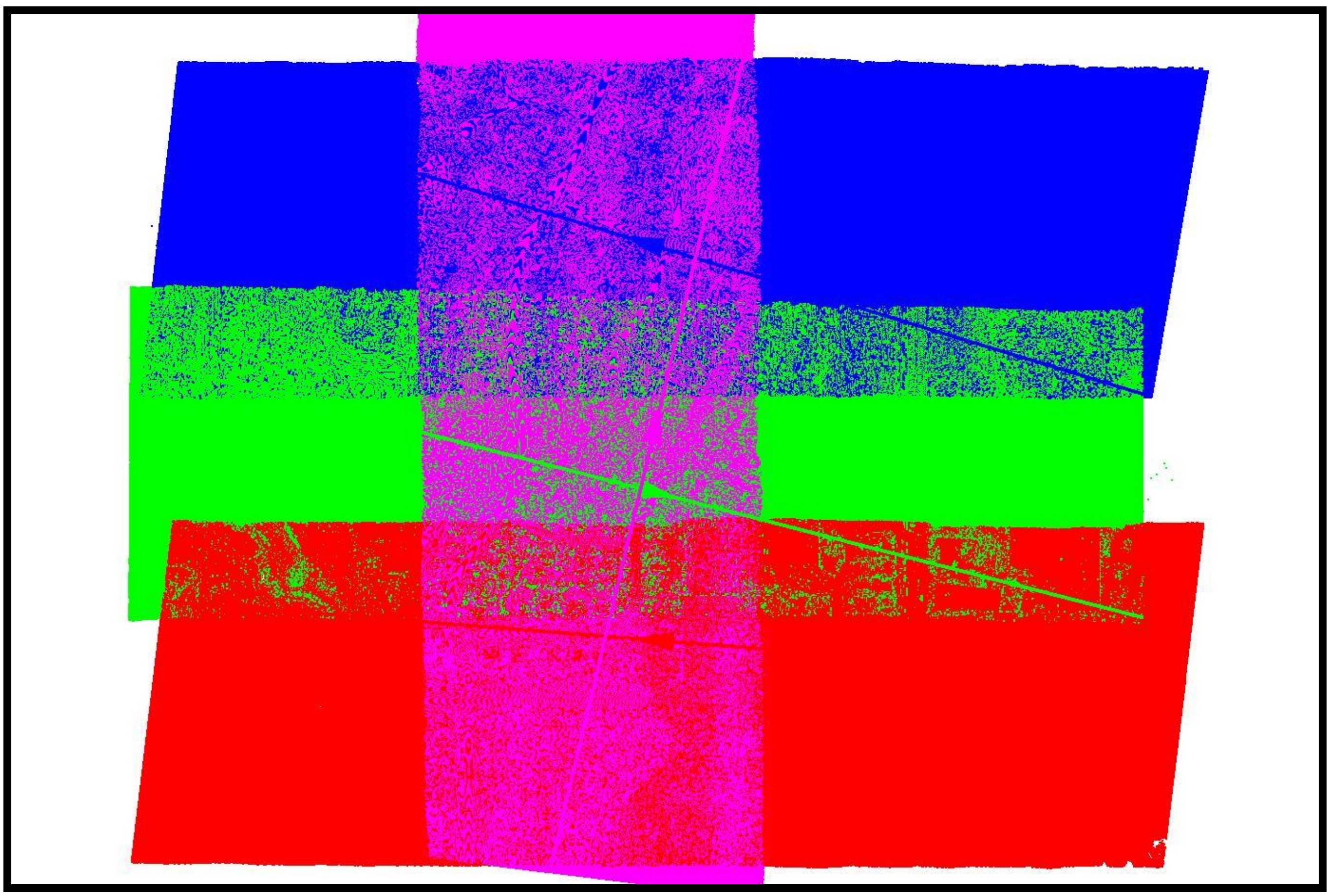
**Initial Processing**

Lidar data is output as LAS point data using Optech's Lidar Mapping Suite (LMS). LMS matches ground and roof planes plus roof lines to self-calibrate and correct system biases. These biases occur within the hardware of the laser scanning systems, within the Inertial Measurement Unit (IMU) and because of environmental conditions which affect the refraction of light. The systemic biases that are corrected for include scale, roll, pitch, and heading.

In addition to the self-calibration mode LMS runs a "production" mode which applies the self-calibration parameters and then analyzes each individual flight line and applies small adjustments to each line to tie overlapping lidar points even more tightly together.

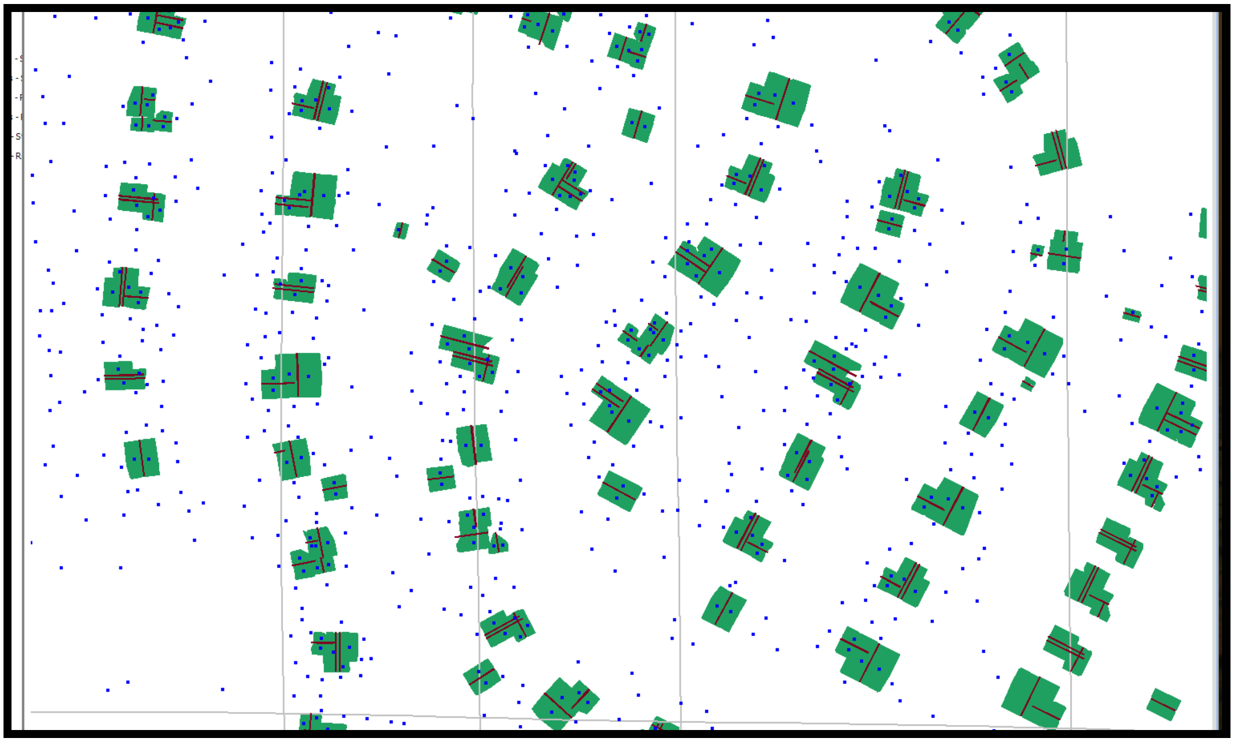
**Boresight Self-Calibration Processing Procedures**

An LMS boresight calibration is performed on an as-needed basis to correct scale, roll, pitch and heading biases. A minimum of three overlapping flights are flown in opposing directions with one cross flight.



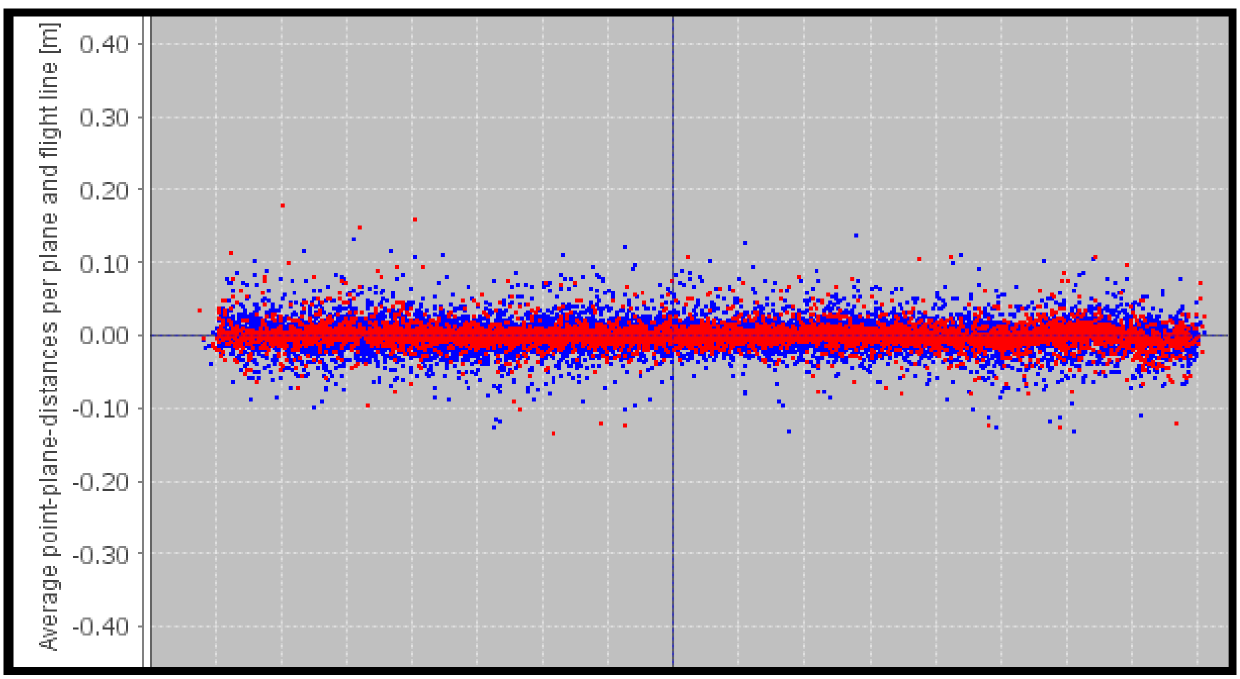
The Boresighting module frees scan angle scale, scan angle lag, XYZ boresight corrections and elevation position corrections while locking scan angle offset and XY position corrections.

The picked calibration site will have a good distribution of buildings for the self-calibration software to match ground planes, roof planes and roof lines.

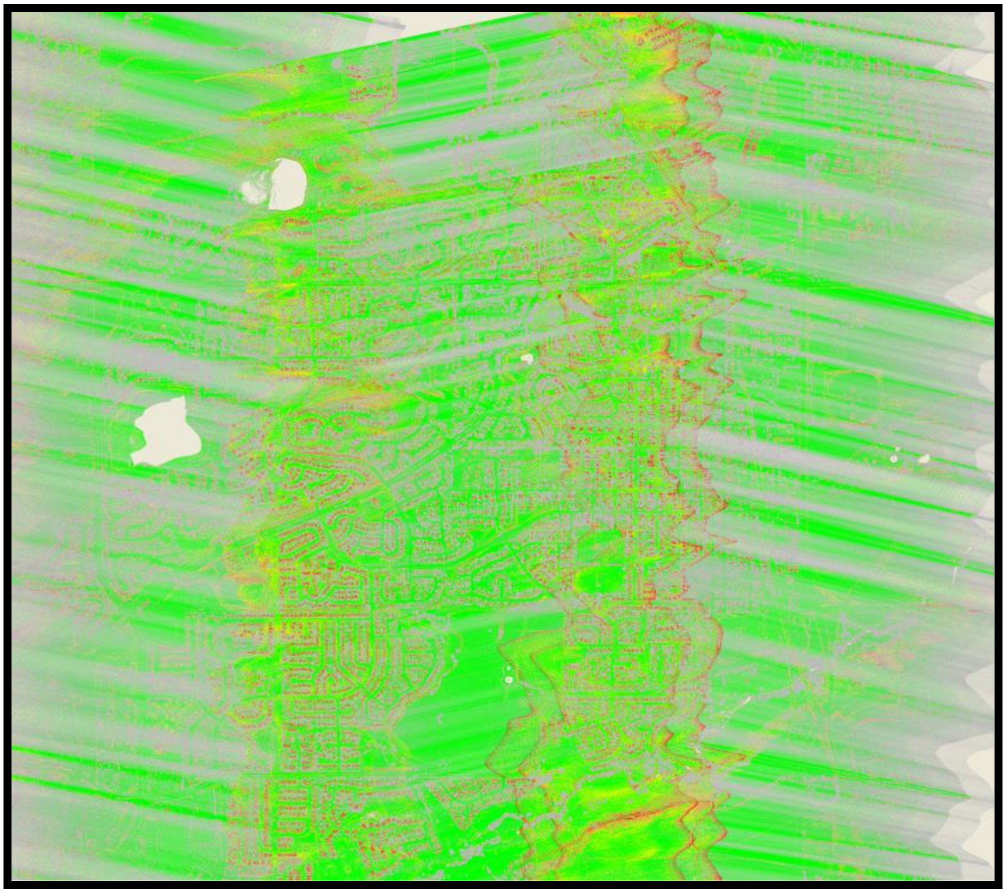


At the conclusion of the self-calibration run the data is quality checked with LMS plots

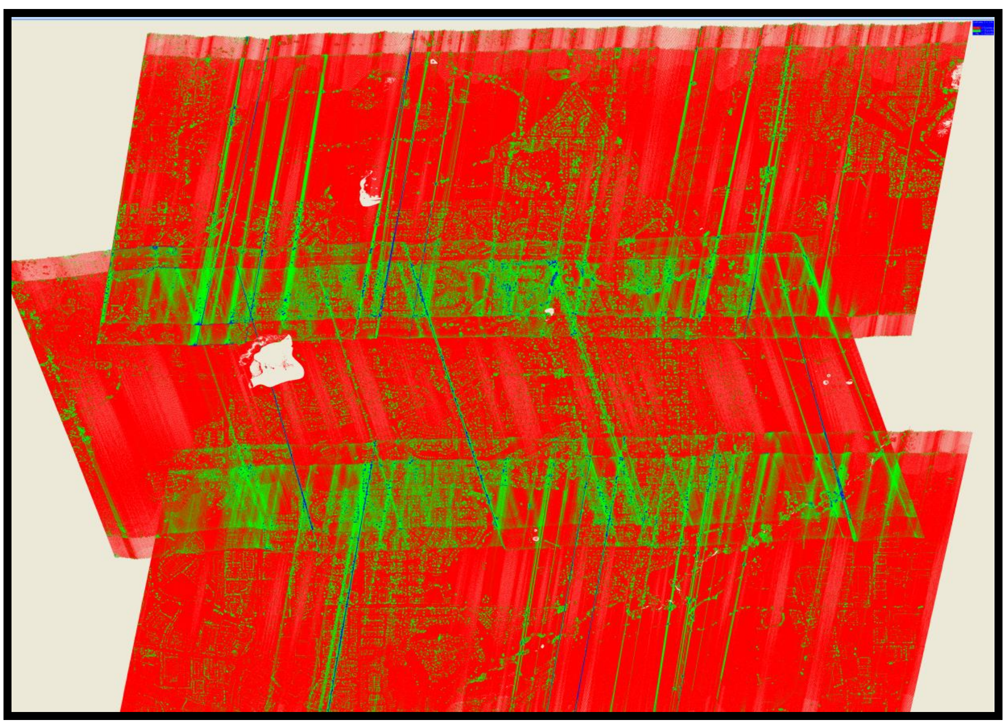
Plot of plane vertical distances from datum plane.



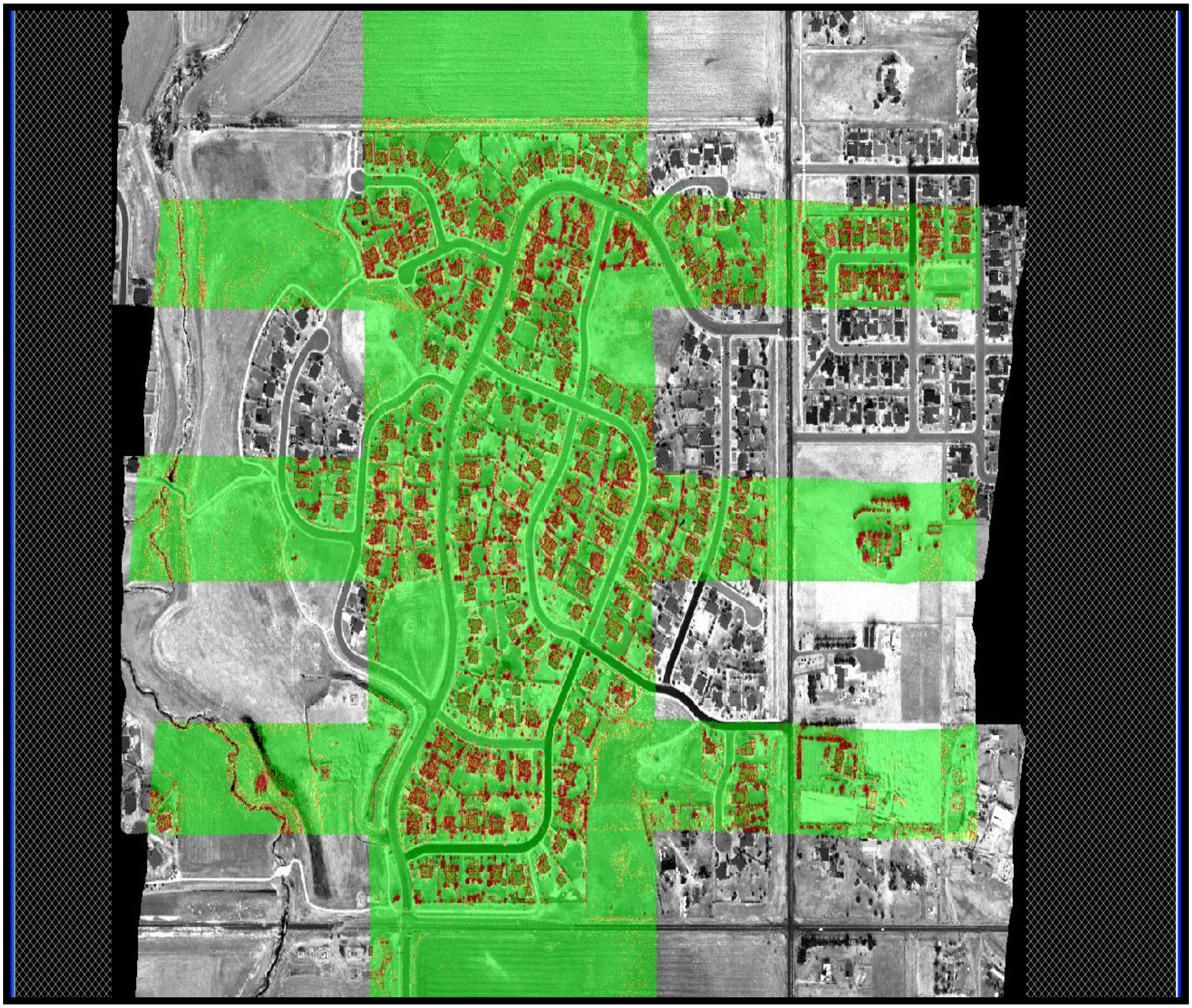
Plot of height differenced between flight lines.  (Green=less than 5cm).



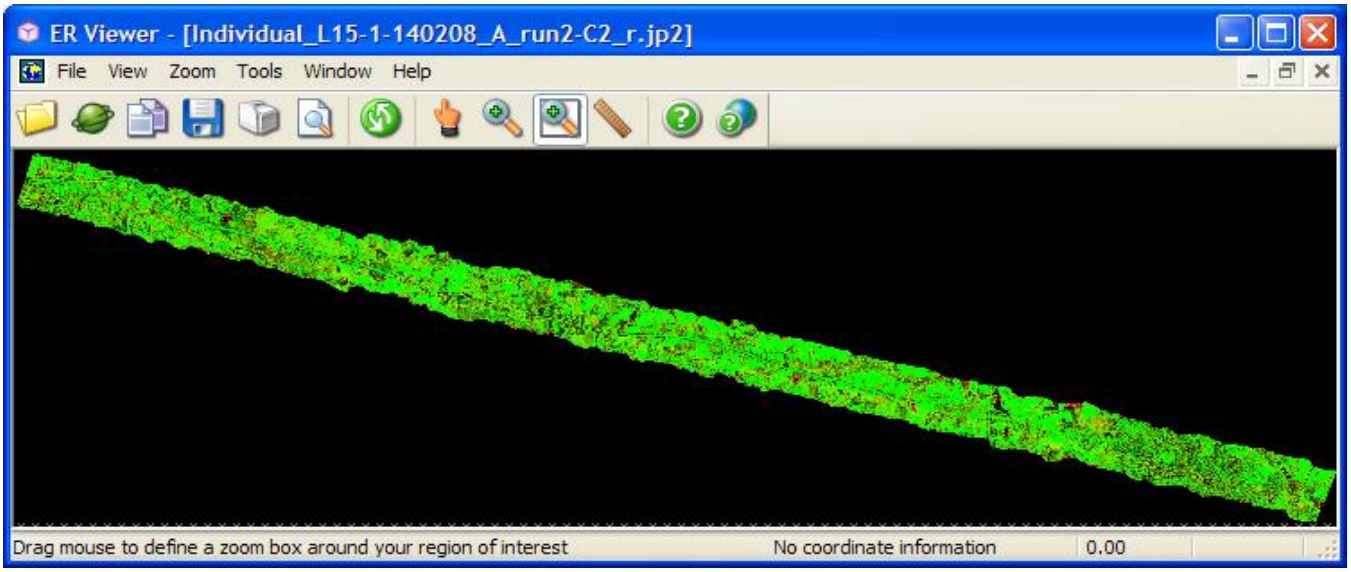
Plot of point densities. (Red=5-9 points per cell, green 10+ points per cell).



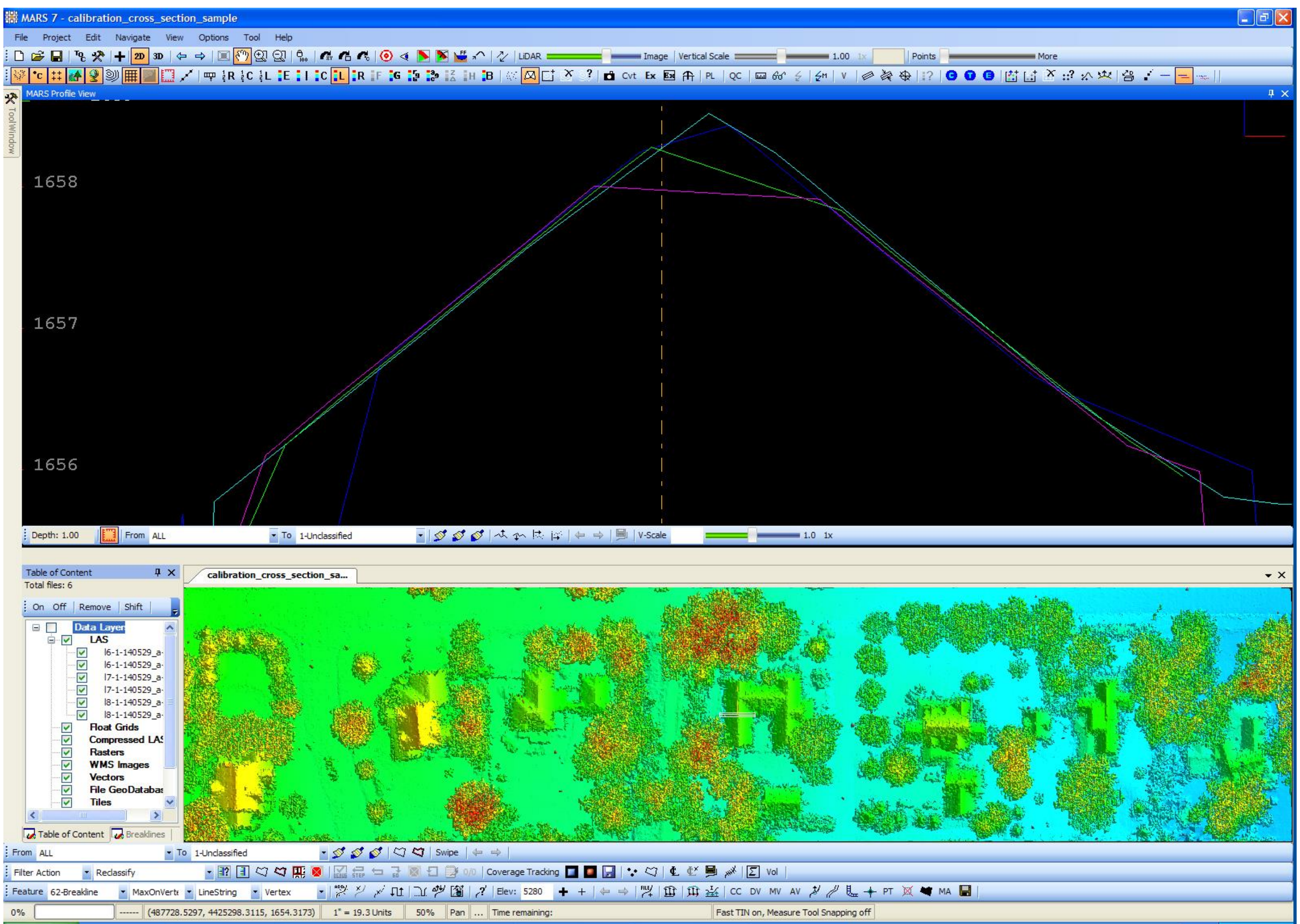
A Flight Line Separation Raster image is generated in Merrick Advanced Remote Sensing Software (MARS®), in this example ground returns from multiple flight lines that are fitting within 3 centimeters are colored green.



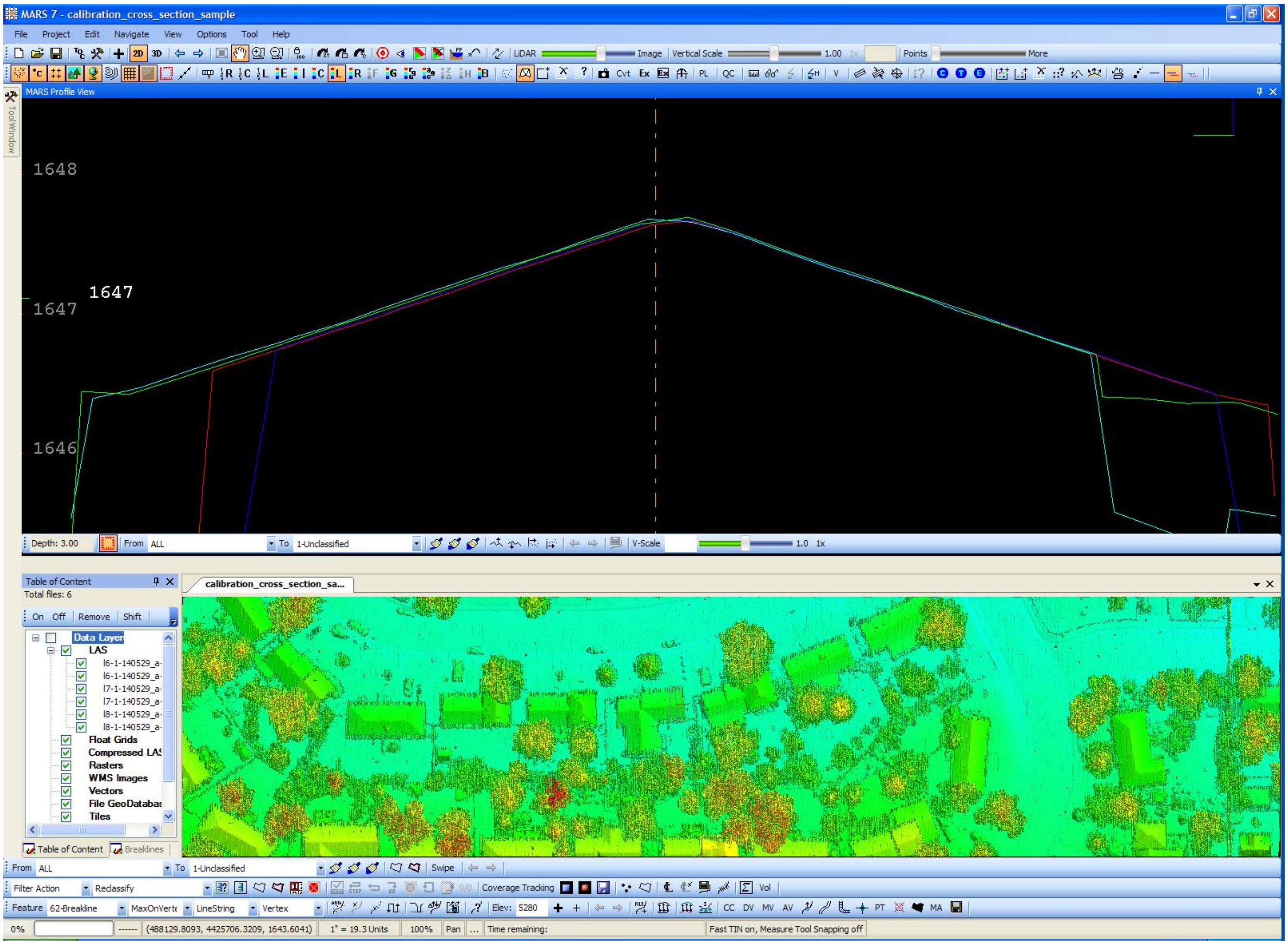
MARS® tests for internal relative vertical accuracy using inbound and outbound scan values. Again, Green is showing inbound and outbound scan data fitting to 3 centimeters.




Building cross sections are checked for good alignment. Pitch and heading are checked on roof planes parallel to the flight direction.



Roll and scale are checked on roof planes perpendicular to the flight direction.

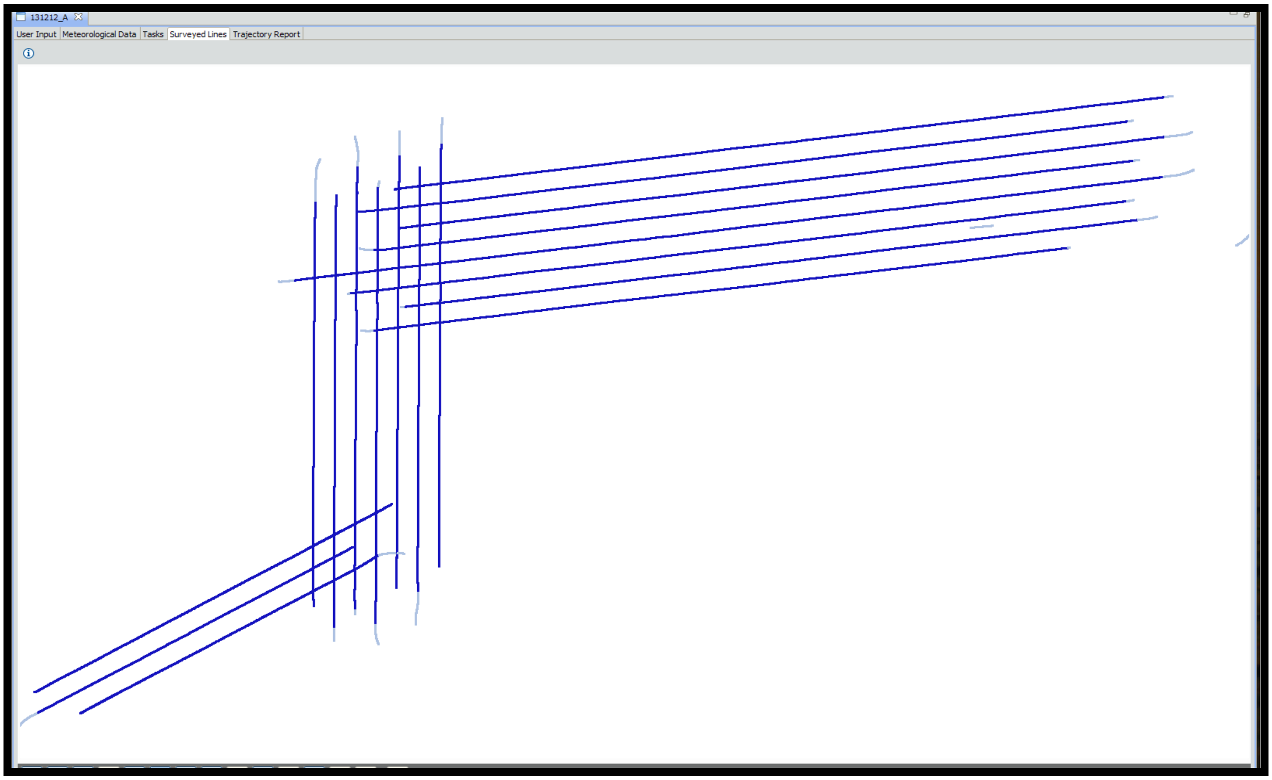



The LMS program outputs a "LCP" file with all the correction parameters. The calibration process may be run several times until the boresight adjustments are acceptable. When the boresight solution is acceptable the LCP file adjustments are saved and also applied to subsequent projects. Each new project is again analyzed and when the adjustment biases show too much drift a new boresight calibration is run. The LCP file may hold calibration tolerances for several projects.

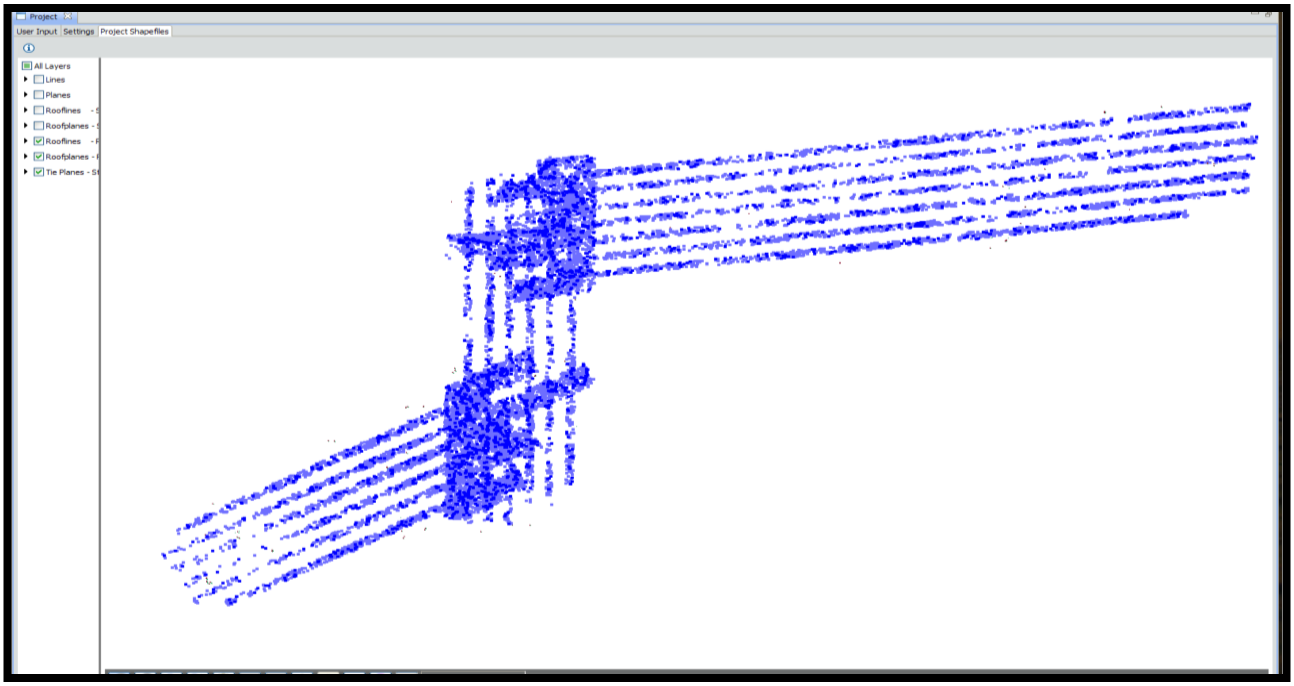
**Block LAS Production Processing Procedures**

The LMS production mode is run on each flight line to further tie the final lidar LAS flight line files tightly together.  Production settings allow scan angle scale, scan angle lag to float and allows elevation to move slightly during flight line to flight line comparison thus further tying flight lines together. A cross flight with locked elevation data is used for controlling flight line elevations.

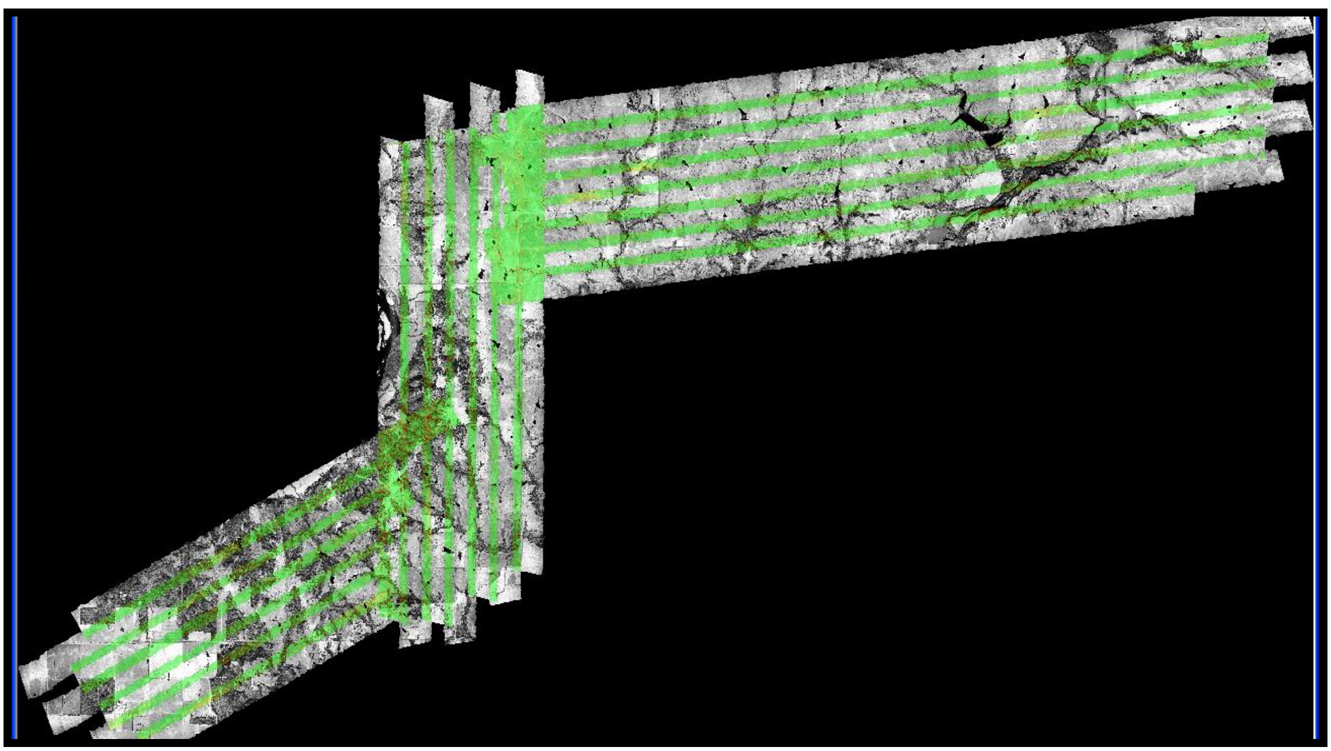
A block of data is selected to process with LMS production settings. Data collected during turns at the ends of flight lines is deselected (light blue lines).



As in self-calibration the LMS production program analyses ground, roof planes and rooflines. One cross flight is locked in elevation and all other lines are adjusted to it. Unlike the calibration site the distribution of roof planes is usually much less dense. Here matched ground tie planes are blue.

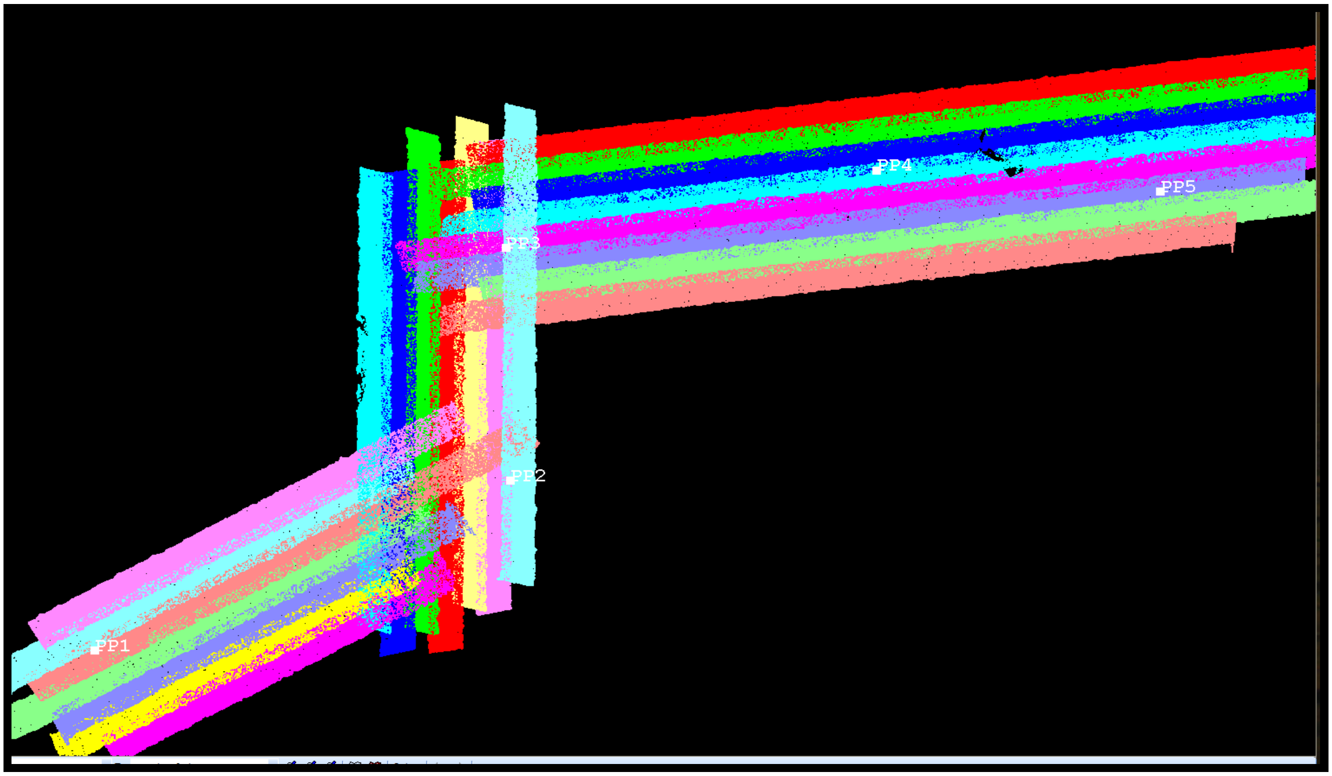



The same quality control outputs used to check self-calibrations are available to analyze the production run. Output plots are again available in LMS and cross sections plus a Flight Line Separation Raster are generated in MARS® to check coverage and quality.



**Correcting the Final Elevation**

After all the lines are tied together a ground control network is imported into MARS®. The ground control network may be pre-existing or collected by a licensed surveyor.




The next step is to match the ground control elevations to the lidar data set. A control report is run and the data set is shifted slightly to zero out the average elevation error and points checked for quality.

The final step before boresighted, leveled LAS files are ready for filtering is to run the MARS® QC Module on the block data. The Boresighted lidar QC Report outputs individual reports on Point Density, Nominal Pulse Spacing, Data Voids, Spatial Distribution, Scan Angles, Control Report, Flight Line Separation, Flight Line Overlap, Buffered Boundary, LAS Formats, Datums and Coordinates.
These reports are checked with the required specifications in the Project Management Plan.

## Appendix 2

**Following is a more detailed orthoimagery project report (AT and Horizontal Accuracy).**

# Aerial Triangulation Report

# 2018

# 014G01218F0028-NE_NRCS

# Ortho LiDAR-2017_D18 project

**Merrick-Surdex JV- Project Number J65219751**

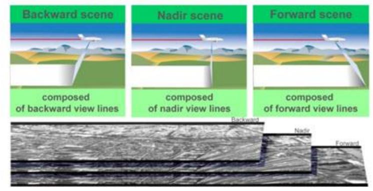
**January 7, 2019**

## 1.0 Overview

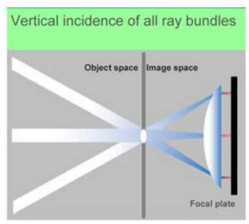
In the Spring of 2018, Merrick-Surdex JV performed aerial triangulation on ADS100 imagery collected from multiple Leica ADS100 aerial sensor systems as part of this mapping project for the United States Geological Survey. All aerial imagery was collected with the support of a GNSS/IMU data collection device that collected precision AirBorne GNSS (ABGPS) exposure station control and precision angular values. The GNSS/IMU data was post processed with the Waypoint Inertial Explorer software to develop precision sensor position and attitude values. All aerial triangulation functions were performed utilizing the latest version of the Leica XPRO software.

ADS 100 camera and accessories
(Courtesy of Leica Geosystems).

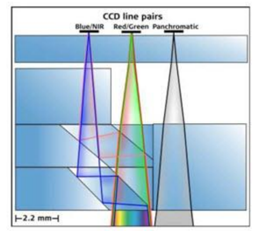
Pushbroom camera acquisition concept
(Courtesy of Leica Geosystems).




Telecentric lens concept
(Courtesy of Leica Geosystems).




Beam splitting to direct light to separate arrays
(Courtesy of Leica Geosystems).




The 60cm leaf off imagery was flown at approximately 24,000’ above mean terrain with flight lines spaced with 30% side overlap. The area encompasses approximately 8,925 square miles and is Platte, Colfax, Dodge, Butler, Saunders, York, Seward, Fillmore, Saline, Oties, Johnson, Nemaha, Richardson and Pawnee counties in Nebraska. The products will include 4 band files at 60 cm pixel orthoimagery tiles in TIF fomats. The image below presents the general layout of the leaf off imagery.

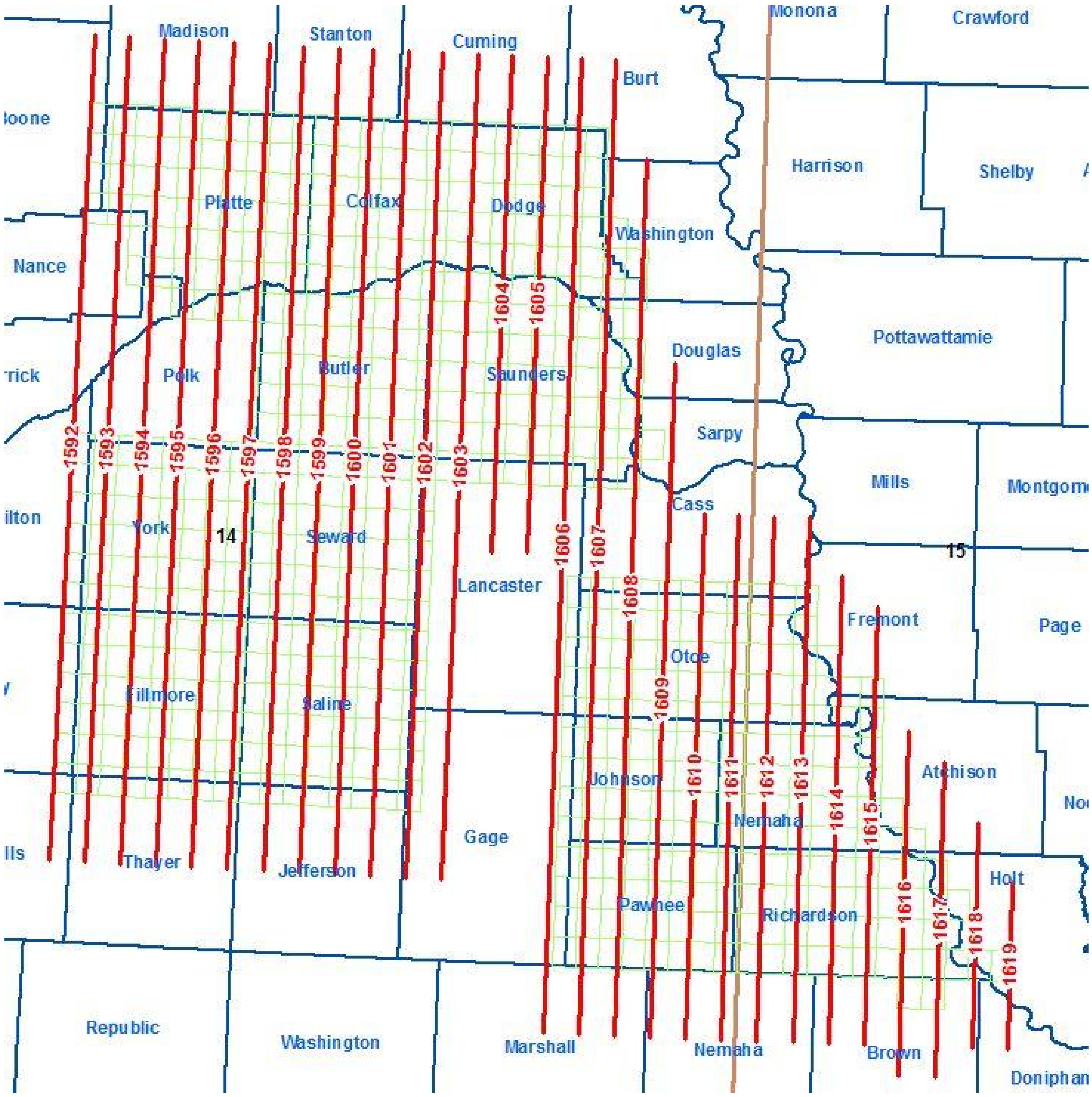



**Figure 1: 60 cm ADS100 Flight Lines**

## 2.0 Ground Control

The ground control for the ortho imagery phase of the project consisted of approximately 58 points distributed throughout the area of interest. The ortho control was a combination of photo identifiable points surveyed after the acquisition of the aerial photography. The graphic below represents layout of the ground control points used for this aerial triangulation. The points were all surveyed by GNSS techniques and processed against NGS monuments in the project area. The final coordinates were derived in UTM14(2011) and UTM15(2011) meters and NAVD88 elevations.

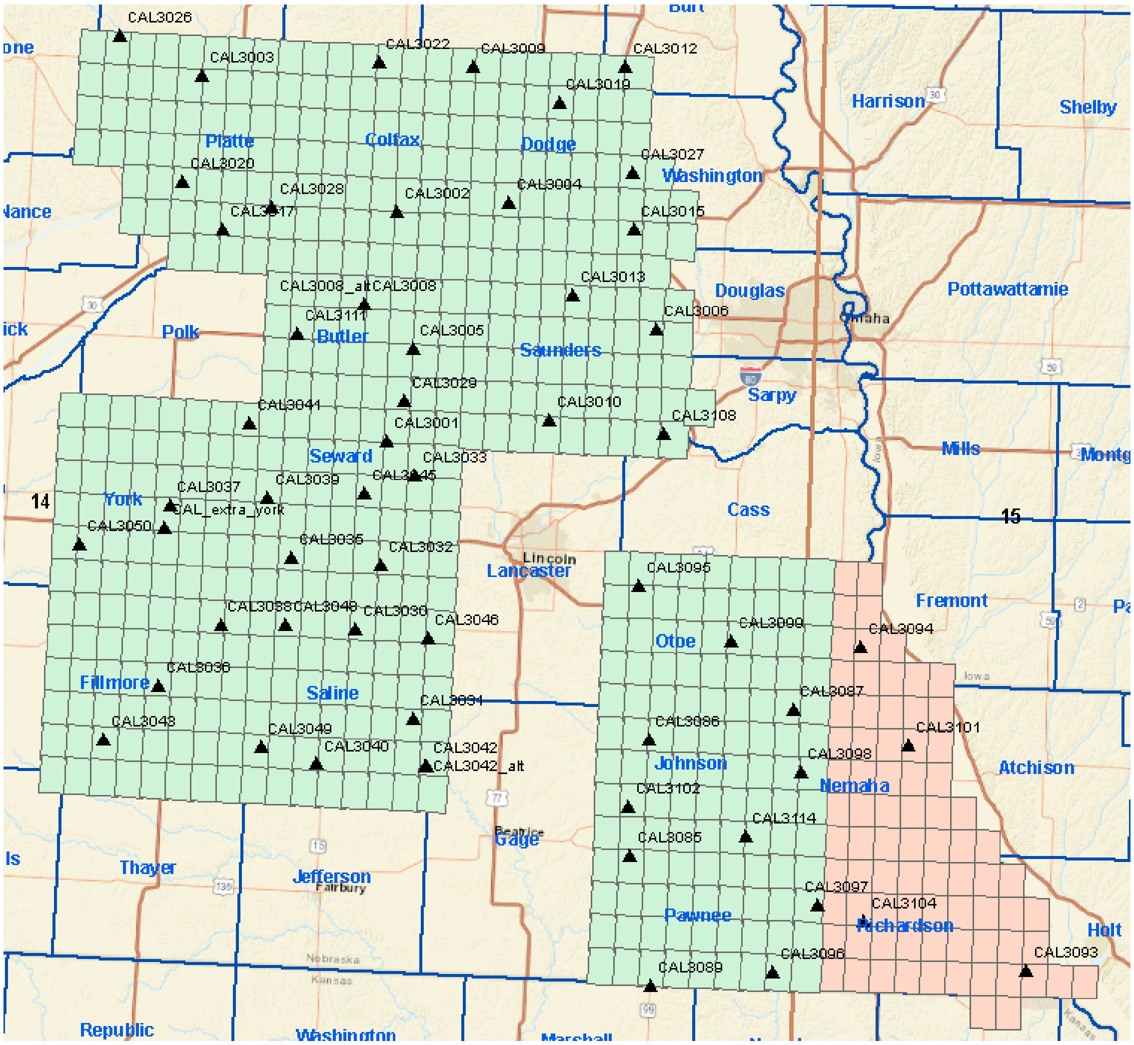



Figure 2: Ground Control Point Distribution

## 3.0 Aerial Triangulation

Aerial triangulation was performed on the 60 cm imagery as one block in the Leica XPro software. The product accuracy requirement of the color digital orthophotography produced under this project is a limiting RMSE in X or Y of 115 cm or less. The following sections of this report summarize the triangulation process.

The horizontal accuracy requirement of the color digital orthophotography produced under this project are defined to meet 4.0 meters of true ground at a 95% confidence level as defined by FGDC-STD-007.3-1998. This accuracy specification at the 95% level can be decomposed into a limiting RMSE in X and Y. These limiting RMSE values are computed to be 115 centimeters. Based upon these product accuracy standards, we would desire the triangulation results to be under ½ the product horizontal accuracy requirement and equal to the horizontal accuracy requirement of the product in Z (this requirement is derived from section 7.7 of the ASPRS Positional Accuracy Standards for Digital Geospatial Data published in November of 2014). Table 1 below presents the limiting triangulation accuracy values for this project.

**Table 1**
**Triangulation Accuracy Limiting Values**

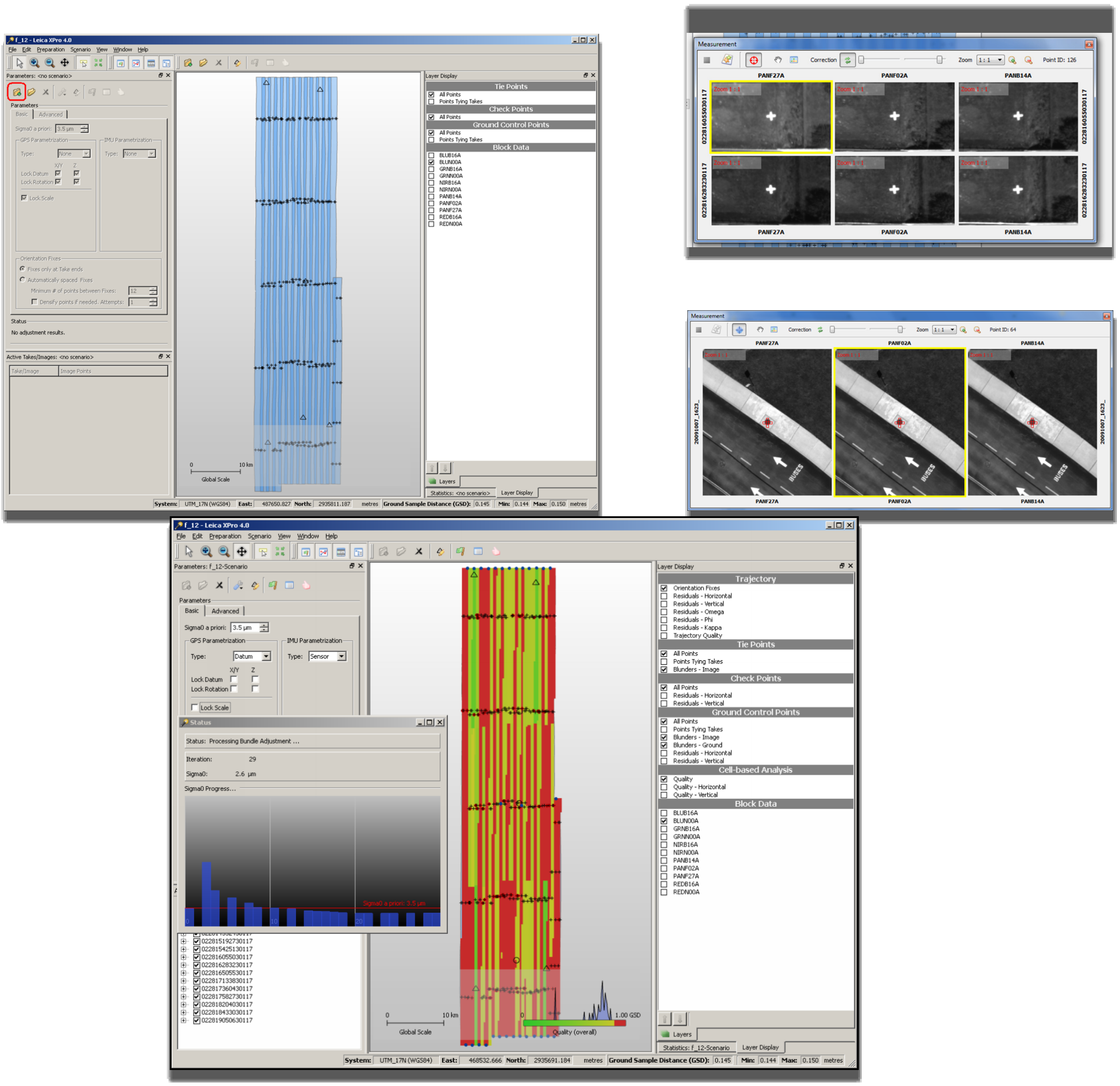
| Product Resolution | Product Accuracy RMSE x or y | AT Limiting Accuracy RMSE x or y | AT Limiting Accuracy RMSEz |
|---|---|---|---|
| 60 cm | 115 cm | 57.5 cm | 115 cm |

## 3.1 60 cm Imagery Aerial Triangulation

The required ground control points, images and GNSS/IMU support data was loaded into XPro. Once in XPro the block was setup with the appropriate parameters weights and initial point measurements were performed. Once completed, the software measured points were run through an ORIMA adjustment. In this adjustment weak and blundered points are automatically removed from the solution. The outcome of this relative adjustment is a set of corrected sensor position and attitude values the accurately model the sensor condition during imagery.

In addition to a textual presentation of the measured points, XPro presents numerous graphical presentations that allow the technicians to refine the triangulation. The graphic below presents several of these graphic displays.

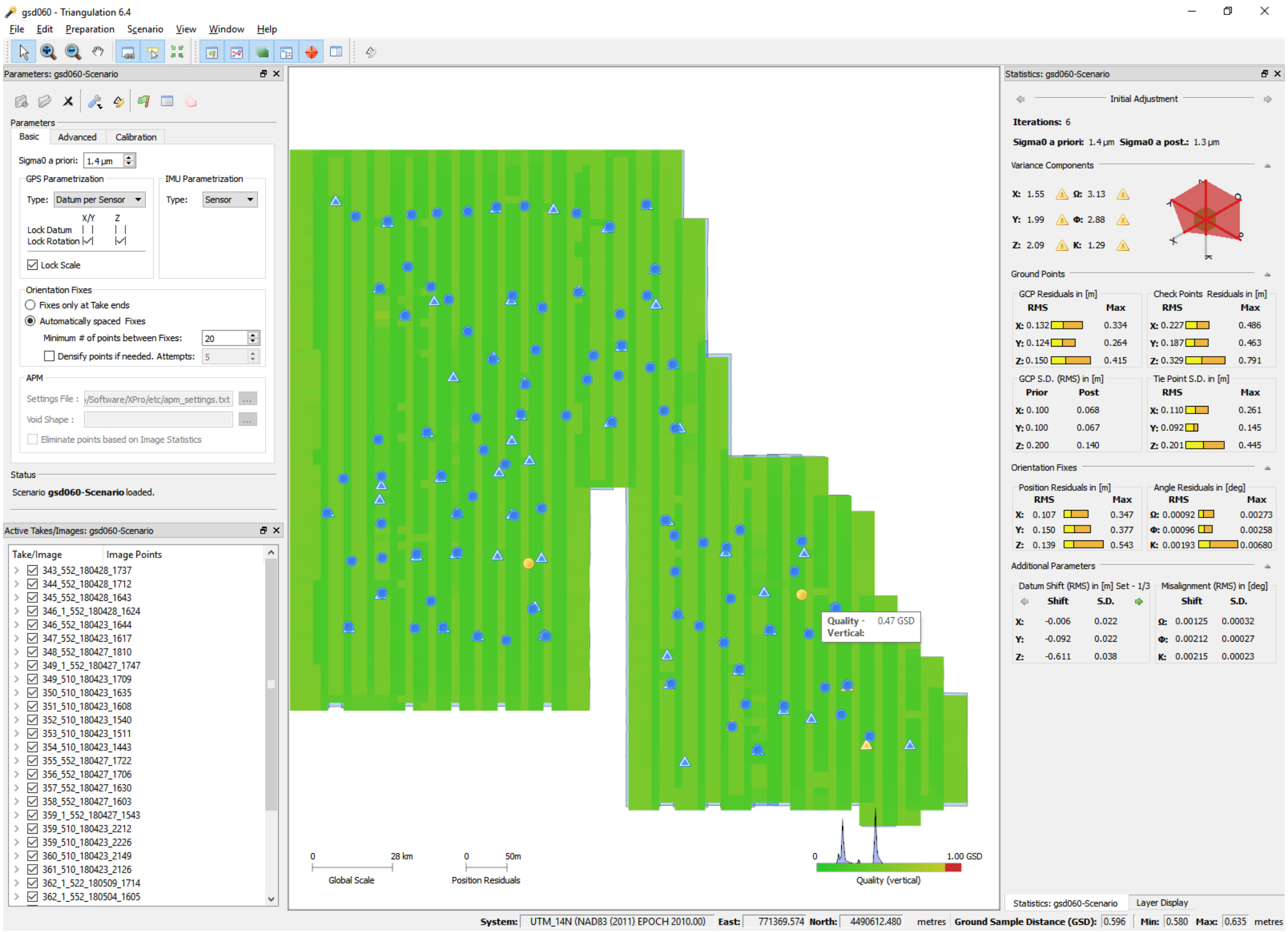
**Leica XPro aerial triangulation software interface.**



### 3.1.1 60-cm Final Imagery Aerial Triangulation

The aerial triangulation of this project was completed in one block tied together by ground control points. The graphics below present that block and its corresponding results. The triangulation concept is to assure that the imagery is adjusted to the ground control within the block. By accomplishing this, the final overall aerial triangulation will meet the project accuracy specifications.

Block solution results are illustrated below.



The key statistics from the aerial triangulation process are summarized in the Table 2 below. All values are meters.

**Table 2**
**Final Aerial Triangulation Statistics**

| Block ID | Image Residuals (μm) | RMSE Control Points (m) | | | RMS GNSS Positions (m) | | | RMS IMU Attitude (deg) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | δX | δY | δZ | δX | δY | δZ | δΩ | δΦ | δK |
| Main | 1.3 | 0.132 | 0.124 | 0.150 | 0.107 | 0.150 | 0.139 | 0.00092 | 0.00096 | 0.00193 |

The block contained 94 Quality Control (QC) points that were also measured in the triangulation. The fit of these points coming out of the triangulation represent an independent assessment of the triangulation accuracy. Table 3 presents a summary of these QC points residuals after the triangulation process.

**Table 3**
**QC Point Statistical Summary**

| Statistic | X Residuals (m) | Y-Residuals (m) | Z-Residuals (m) |
|---|---|---|---|
| N | 94 | 94 | 94 |
| Minimum | -0.47 | -0.45 | -0.79 |
| Maximum | 0.49 | 0.42 | 0.78 |
| Average | -0.03 | 0.02 | 0.01 |
| Standard Deviation | 0.23 | 0.19 | 0.33 |
| RMSE | 0.23 | 0.19 | 0.33 |

In Table 1 of this report we established the limiting RMSE of the triangulation to meet our mapping standards. Table 4 below presents these requirements again and compares them to the computed accuracy from the aerial triangulation QC points provided in Table 3 above.

**Table 4**
**Triangulation Accuracy Assessment**

| Component | Specification Limiting RMSE | QC Point RMSE | Status |
|---|---|---|---|
| X | 57.5 cm | 23 cm | Passed |
| Y | 57.5 cm | 19 cm | Passed |
| Z | 115 cm | 33 cm | Passed |

Based on these limiting values and the observed QC point residuals in the triangulation, it is my assessment that this aerial triangulation meets the accuracy requirements to support further production of digital orthophotography to NSSDA accuracy standards of a 4 meter accuracy at the 95% confidence level.

Respectfully submitted,

Steven M. Kasten CP, PLS
January 7, 2019

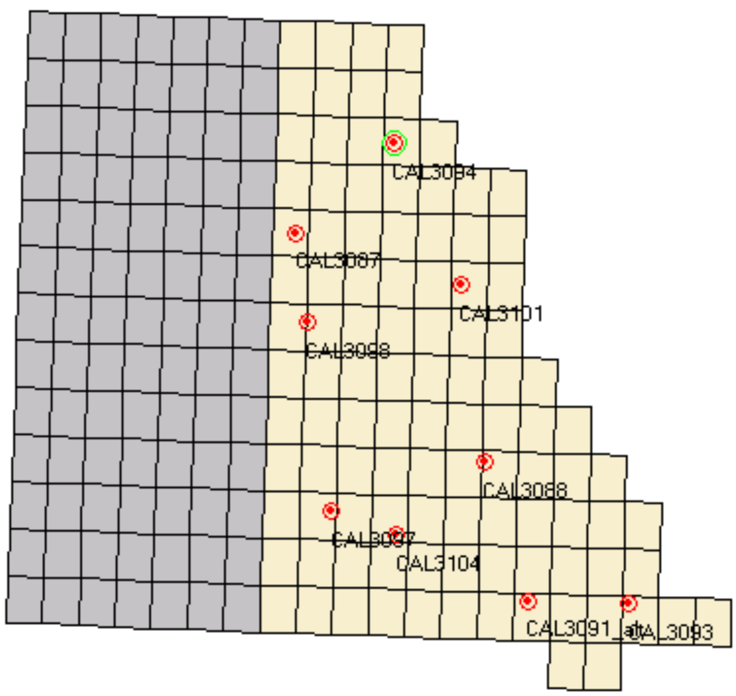
## Project Information

Prepared By: JG
Project Name: Nebraska 60cm
Sensor Info: ADS100
Sensor Resolution: 0.6
Vendor Name: Merrick-Surdex JV
Date of Aquisition: Start: 8/6/2018 Finish: 8/6/2018

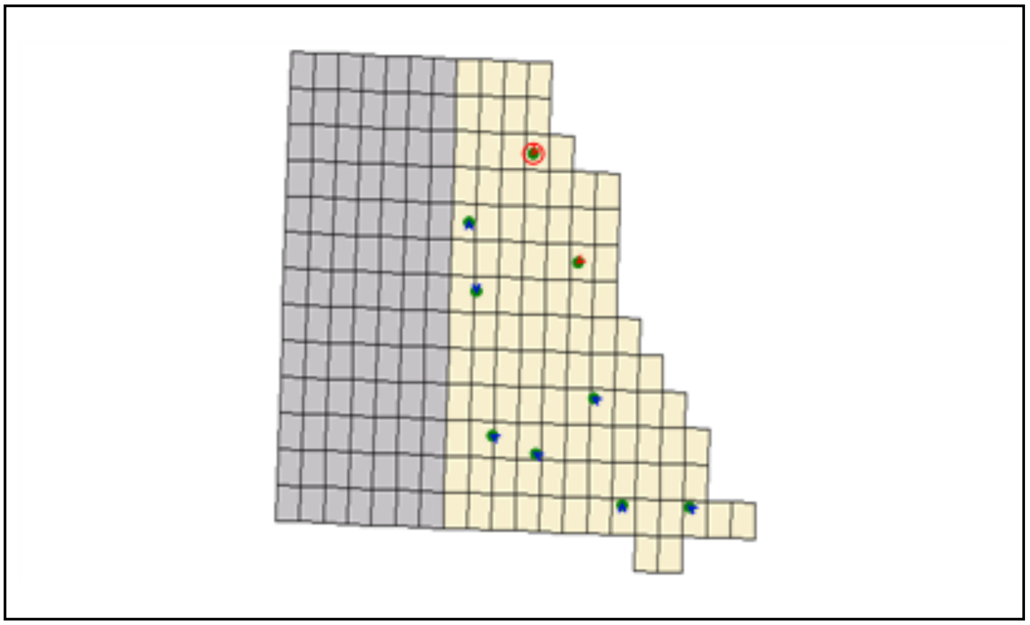
## Metadata Information

Index File Name: AA_SHP_tile.shp
# of Polygons: 222
# of Matching Images: 131
Polygon ID: Name
Units: Meters
Image Folder Path: I:\2800105\product_tiles\Client_SE_UTM15_hr4\Delivery\2018-08-03_112458
Threshold: CE90: 0.349
Scaling Used: 1:800

## Tiled-Image Area

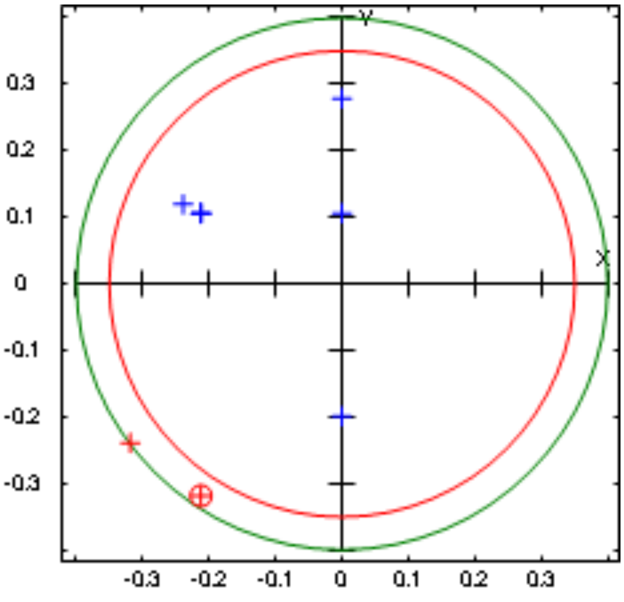


## Vector Offset



Scaling Factor: 200

## Circular Error




## Error Statistics

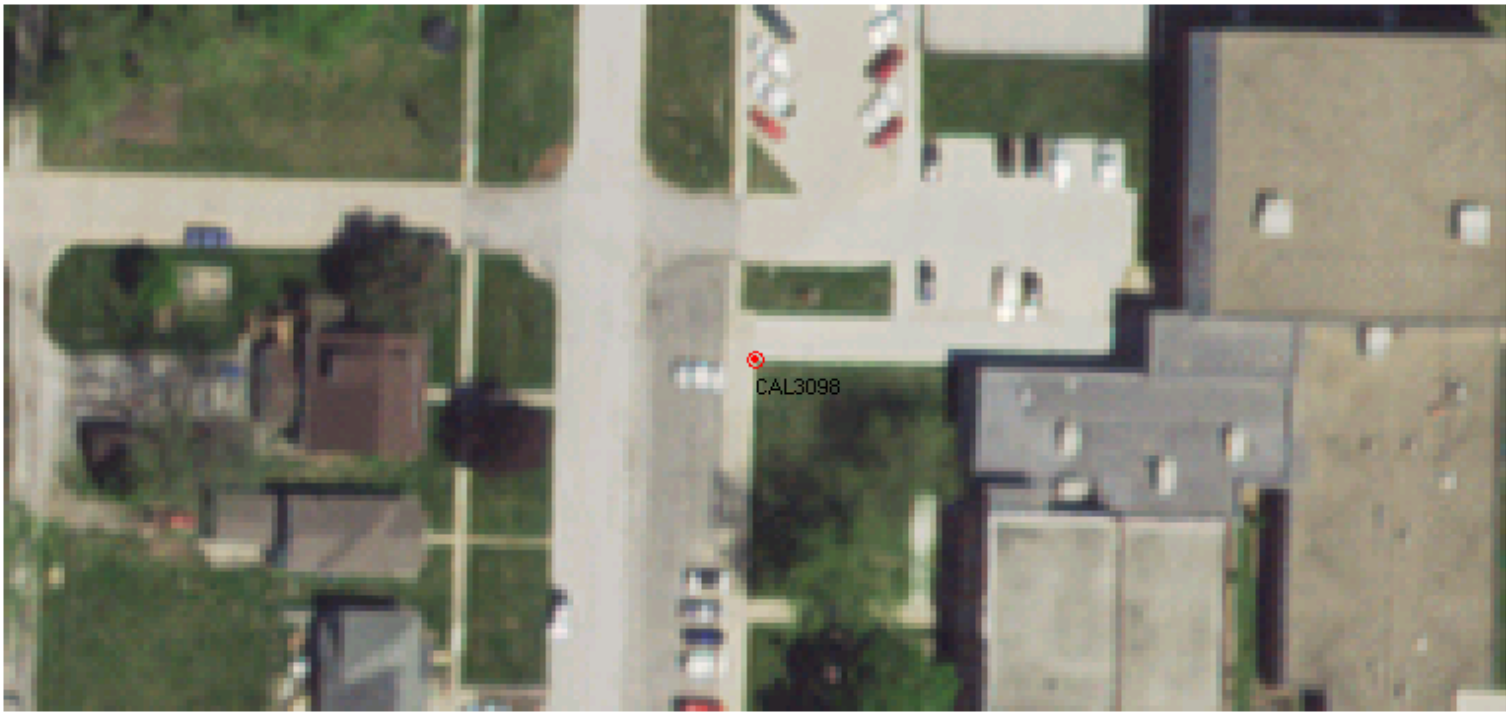
| | | | |
|---|---|---|---|
| Min ΔX: | -0.318 | CE 95: | 0.398 |
| Min ΔY: | -0.318 | Skew ΔX: | 0.525 |
| Max ΔX: | 0 | Skew ΔY: | -0.622 |
| Max ΔY: | 0.278 | Horiz. Bias: | 0.156 |
| Mean ΔX: | -0.156 | SRMSE H: | 0.054 |
| Mean ΔY: | 0.007 | CI: | 0.106 |
| RmseX: | 0.193 | | |
| RmseY: | 0.192 | | |
| RmseH: | 0.273 | | |
| NSSDA: | 0.472 | | |
| No. Obs.: | 9 | | |
| SX: | 0.122 | | |
| SY: | 0.204 | | |
| SH: | 0.163 | | |
| CE 90: | 0.349 | | |

## Coordinates and Offsets of Analyzed Locations

| | | ID | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Survey X | Survey Y | Photo X | Photo Y | ΔX | ΔY |
| 1) | ☑ | **CAL3098** | | | | | | |
| | | | 245640.85 | 4477865.01 | 245640.847 | 4477864.812 | 0 | -0.198 |
| 2) | ☑ | **CAL3101** | | | | | | |
| | | | 268235.86 | 4483377.538 | 268235.541 | 4483377.3 | -0.318 | -0.238 |
| 3) | ☑ | **CAL3087** | | | | | | |
| | | | 244029.42 | 4491123.726 | 244029.421 | 4491124.004 | 0 | 0.278 |
| 4) | ☑ | **CAL3094** | | | | | | |
| | | | 258320.47 | 4504308.325 | 258320.254 | 4504308.007 | -0.212 | -0.318 |
| 5) | ☑ | **CAL3088** | | | | | | |
| | | | 271753.22 | 4457266.815 | 271753.003 | 4457266.921 | -0.212 | 0.106 |
| 6) | ☑ | **CAL3091_alt** | | | | | | |
| | | | 278061.36 | 4436760.551 | 278061.362 | 4436760.657 | 0 | 0.106 |
| 7) | ☑ | **CAL3093** | | | | | | |
| | | | 293024.25 | 4436356.333 | 293024.038 | 4436356.439 | -0.212 | 0.106 |
| 8) | ☑ | **CAL3097** | | | | | | |
| | | | 249199.77 | 4450089.697 | 249199.533 | 4450089.816 | -0.238 | 0.119 |
| 9) | ☑ | **CAL3104** | | | | | | |
| | | | 258830.48 | 4446616.447 | 258830.27 | 4446616.553 | -0.212 | 0.106 |

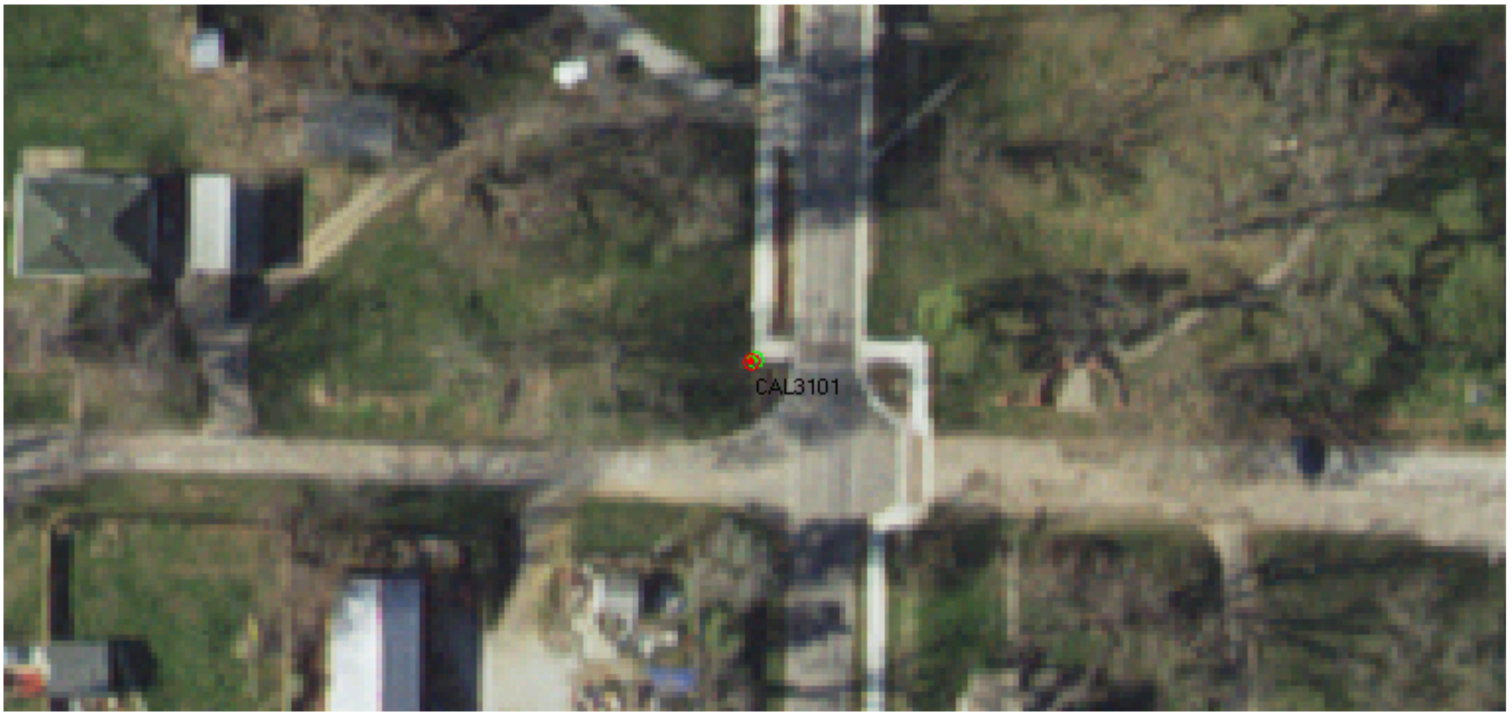
## Point CAL3098:

**X1: 245640.847** **Y1: 4477865.01** **X2: 245640.847** **Y2: 4477864.812** **Delta X: 0** **Delta Y: -0.198**



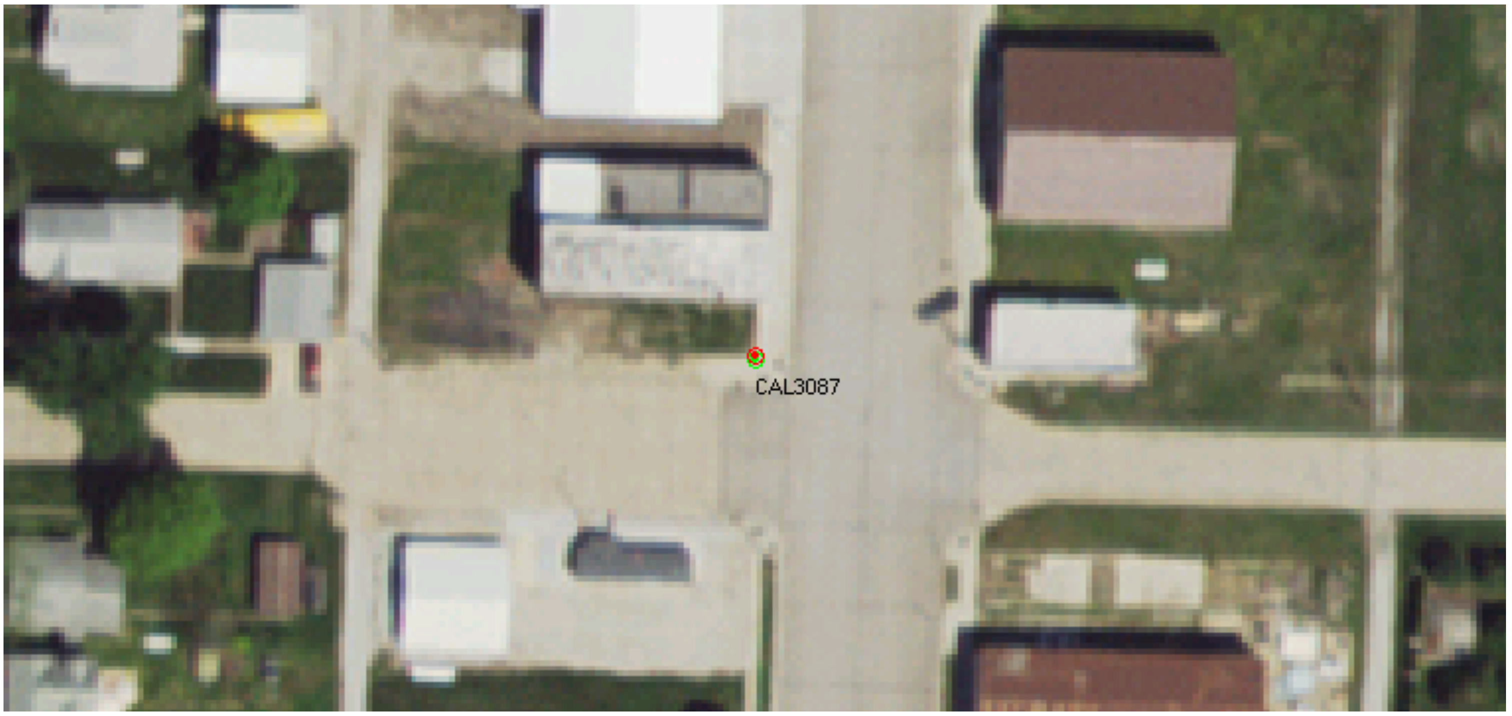

## Point CAL3101:

**X1: 268235.859** **Y1: 4483377.538** **X2: 268235.541** **Y2: 4483377.3** **Delta X: -0.318** **Delta Y: -0.238**



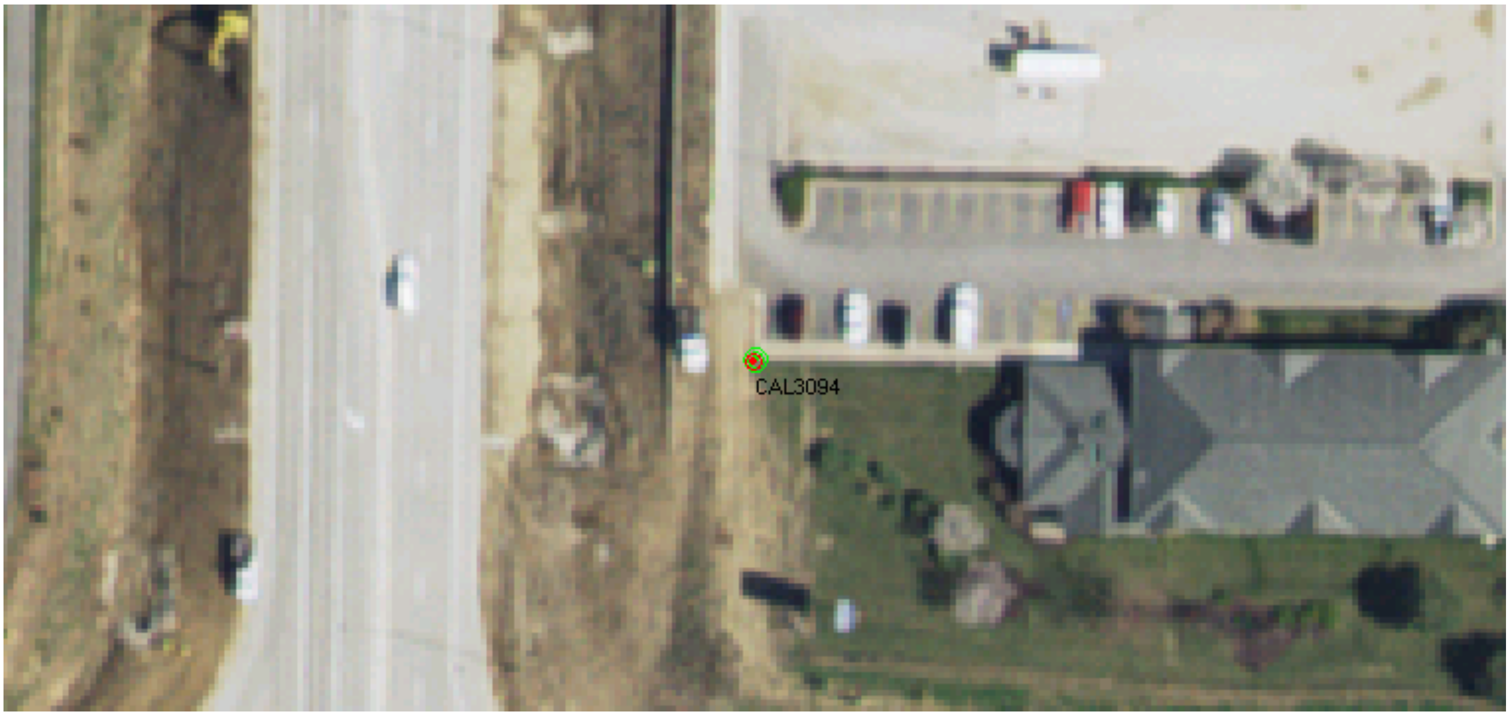
**Point CAL3087:**

X1: 244029.421 Y1: 4491123.726 X2: 244029.421 Y2: 4491124.004 Delta X: 0 Delta Y: 0.278



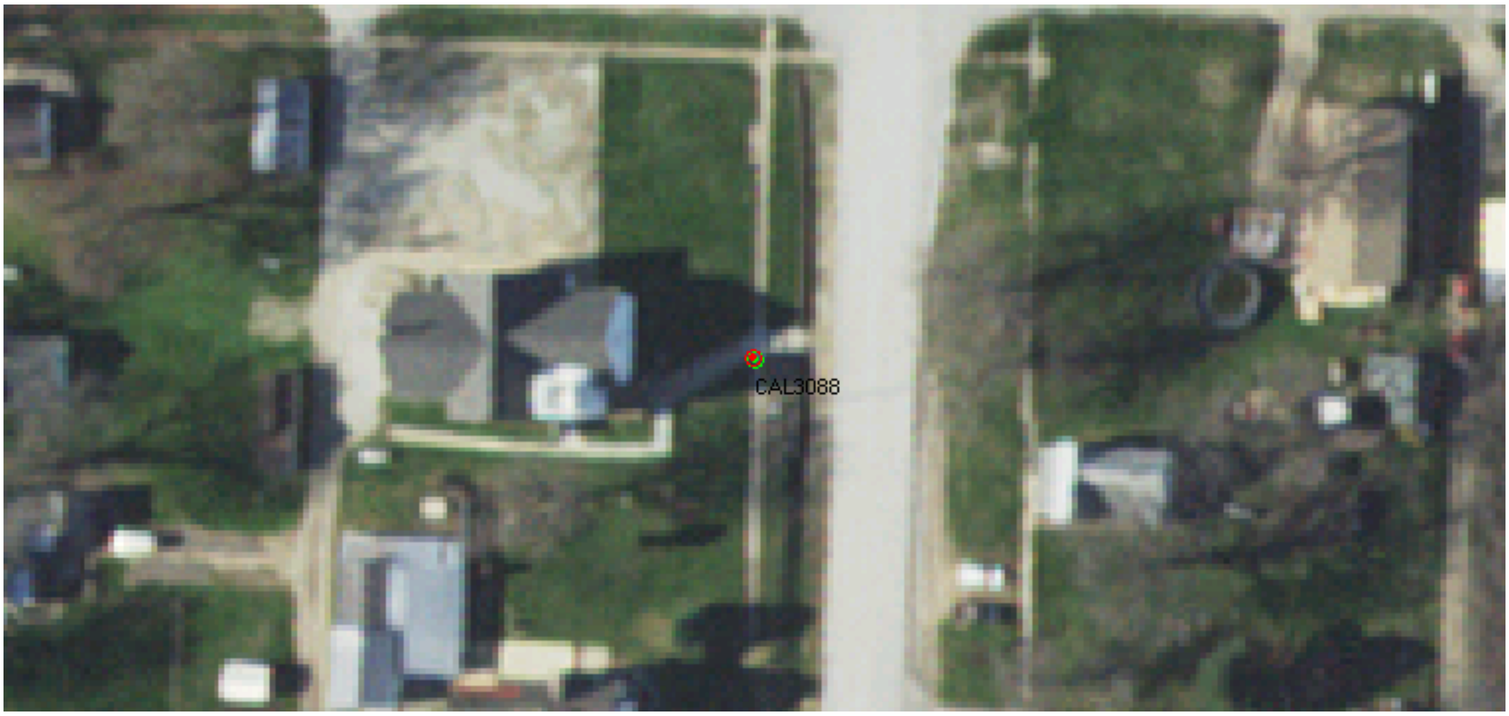

**Point CAL3094:**

X1: 258320.466 Y1: 4504308.325 X2: 258320.254 Y2: 4504308.007 Delta X: -0.212 Delta Y: -0.318



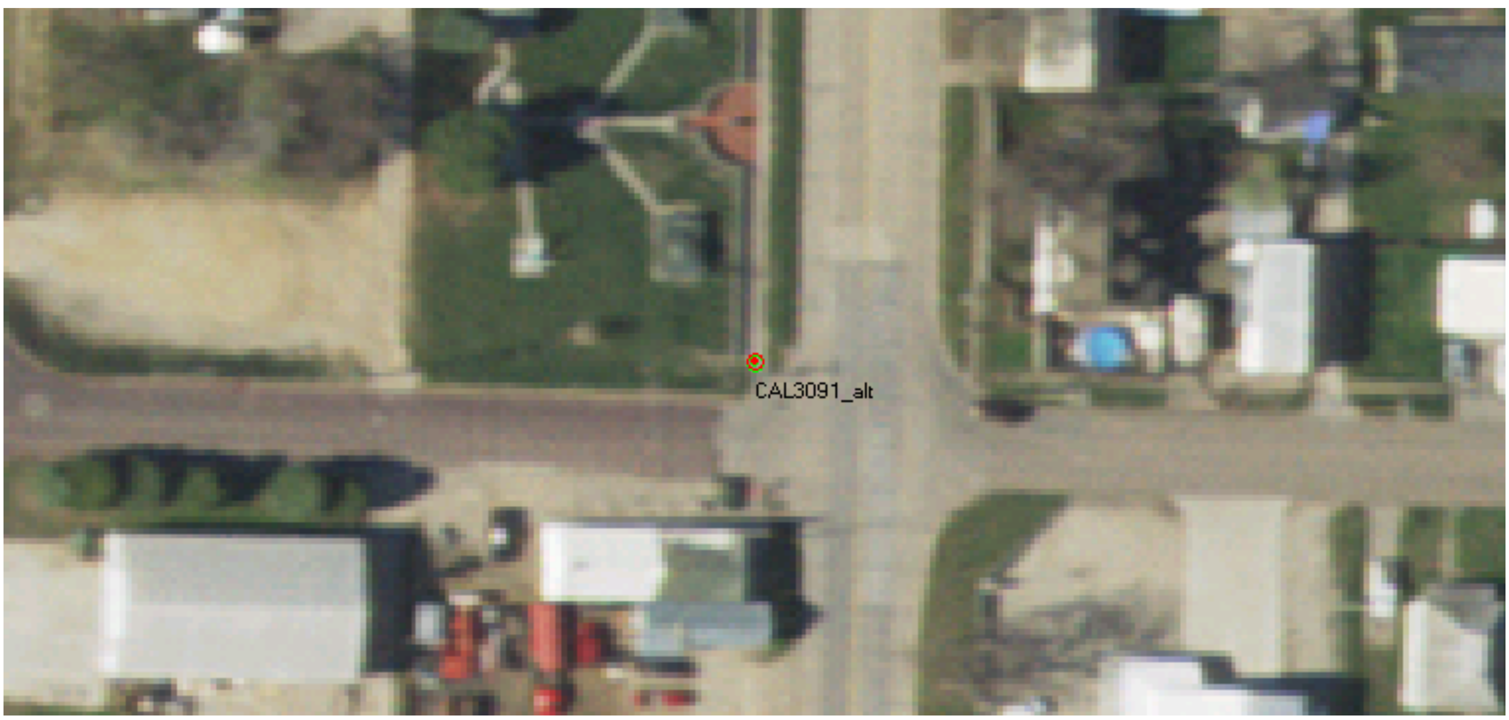
## Point CAL3088:

**X1: 271753.215 Y1: 4457266.815 X2: 271753.003 Y2: 4457266.921 Delta X: -0.212 Delta Y: 0.106**



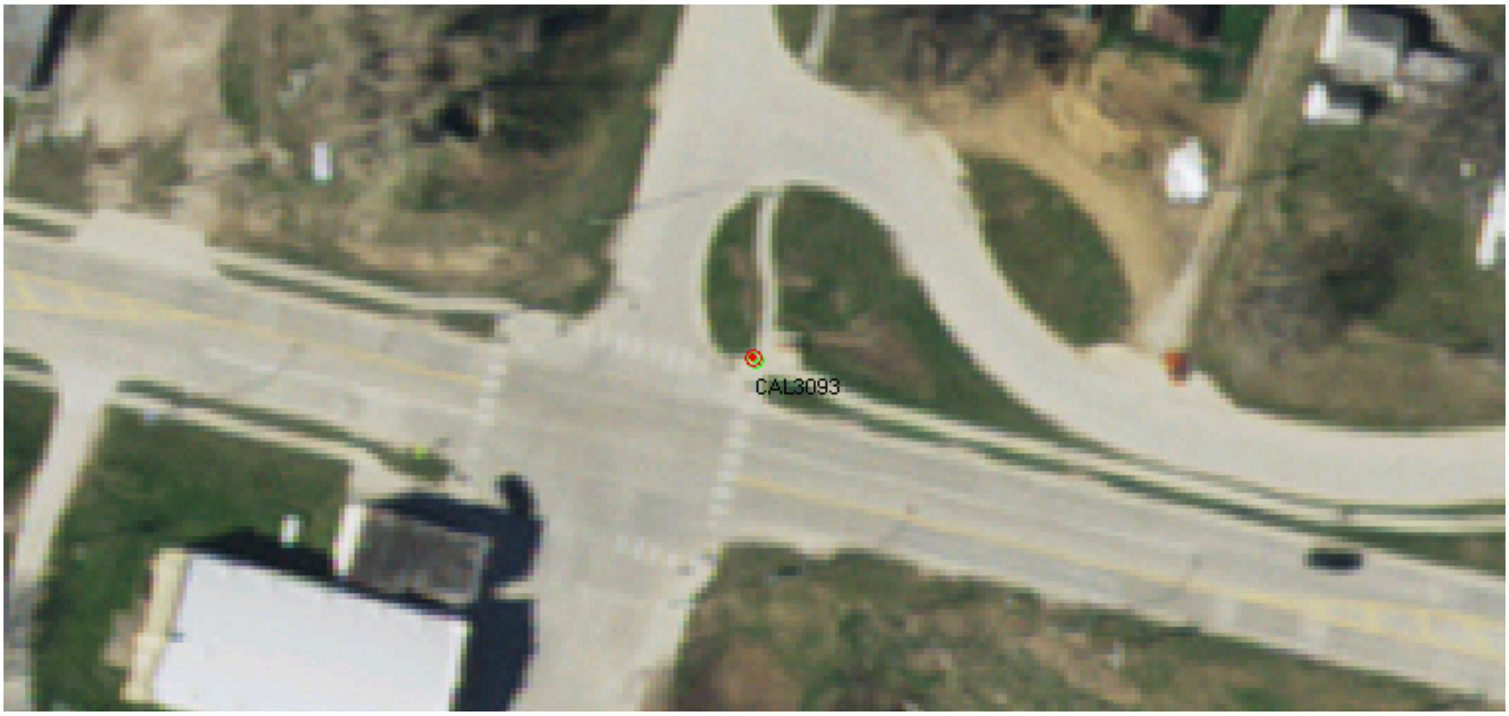

## Point CAL3091_alt:

**X1: 278061.362 Y1: 4436760.551 X2: 278061.362 Y2: 4436760.657 Delta X: 0 Delta Y: 0.106**



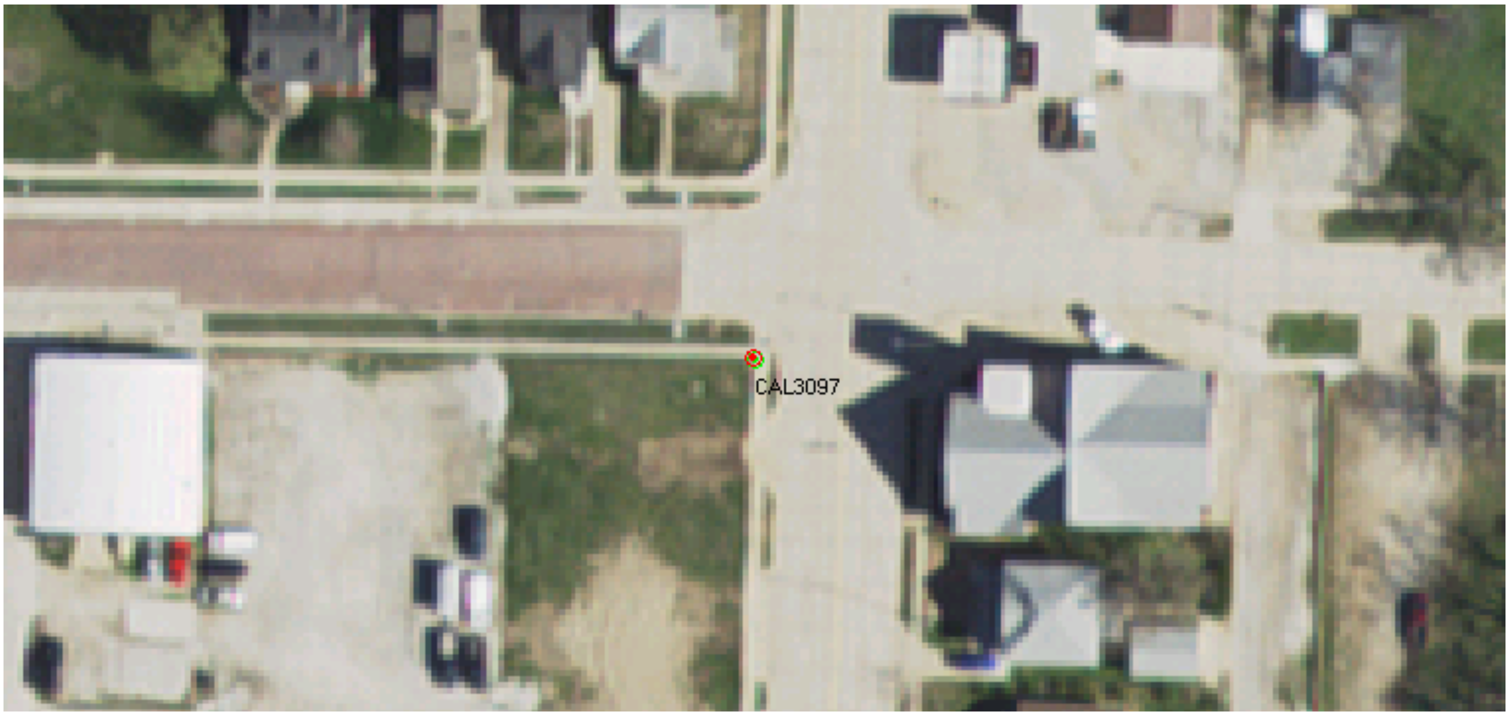
**Point CAL3093:**

**X1: 293024.25** **Y1: 4436356.333** **X2: 293024.038** **Y2: 4436356.439** **Delta X: -0.212** **Delta Y: 0.106**




**Point CAL3097:**

**X1: 249199.771** **Y1: 4450089.697** **X2: 249199.533** **Y2: 4450089.816** **Delta X: -0.238** **Delta Y: 0.119**



**Point CAL3104:**

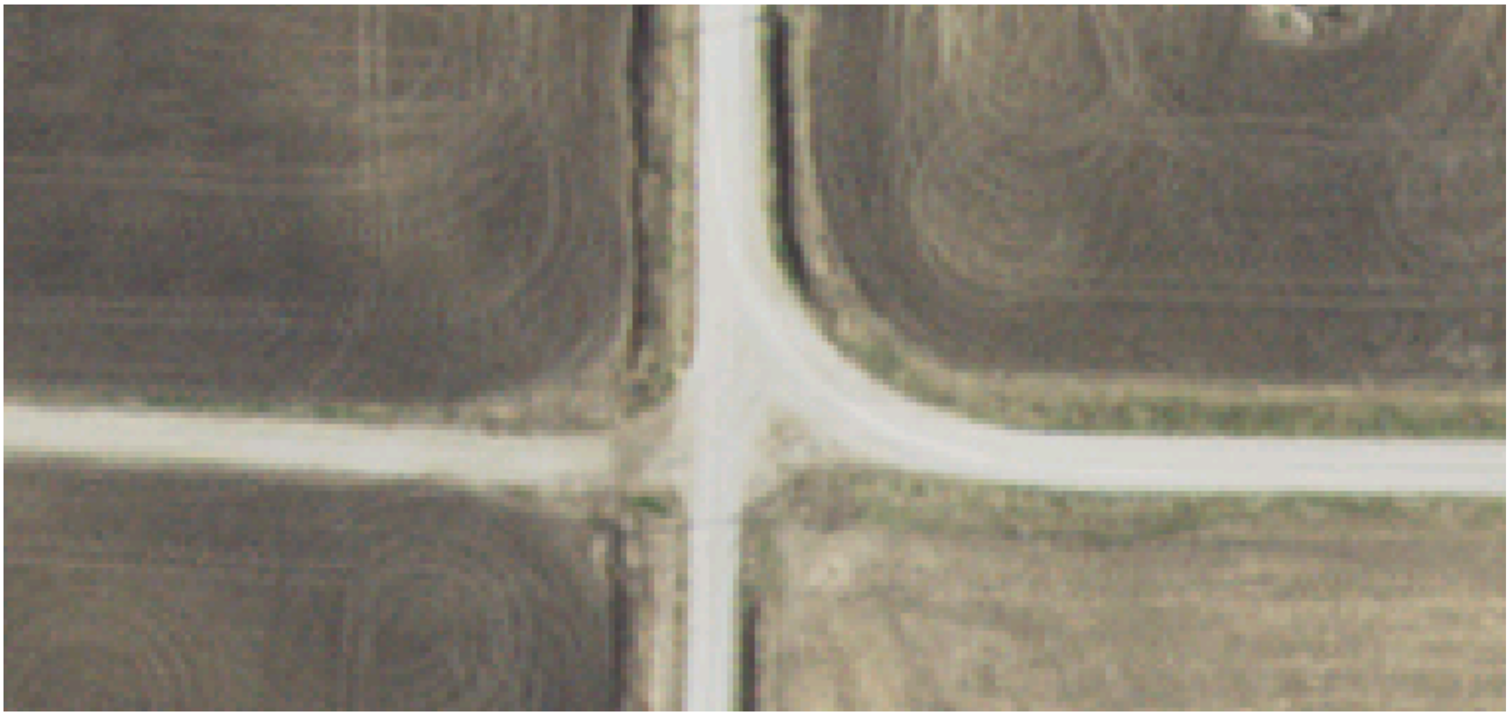
**X1: 258830.482　Y1: 4446616.447　X2: 258830.27　Y2: 4446616.553　Delta X: -0.212　Delta Y: 0.106**

## Coordinates and Offsets of Unanalyzed Locations

| | | ID | | | |
|---|---|---|---|---|---|
| | | | Survey X | Survey Y | Reason For Exclusion |
| 1) | ☐ | CAL3113 | | | |
| | | | 273131.346 | 4490116.178 | Ambigious Location |
| 2) | ☐ | CAL3103 | | | |
| | | | 254261.71 | 4517266.11 | |
| 3) | ☐ | CAL3105 | | | |
| | | | 246051.673 | 4512727.997 | Ambigious Location |
| 4) | ☐ | CAL3090 | | | |
| | | | 275624.765 | 4447237.837 | Ambigious Location |
| 5) | ☐ | CAL3091 | | | |
| | | | 278036.156 | 4436781.307 | Obscure Location |
| 6) | ☐ | CAL3106 | | | |
| | | | 283262.665 | 4455134.453 | Obscure Location |

## Point CAL3113:

**X1: 273131.346 Y1: 4490116.178 Reason For Exclusion: Ambigious Location**



## Point CAL3103:

**X1: 254261.71 Y1: 4517266.11 Reason For Exclusion:**

## Point CAL3105:

**X1: 246051.673 Y1: 4512727.997 Reason For Exclusion: Ambigious Location**

## Point CAL3090:

**X1: 275624.765 Y1: 4447237.837 Reason For Exclusion: Ambigious Location**

## Point CAL3091:

**X1: 278036.156 Y1: 4436781.307 Reason For Exclusion: Obscure Location**

## Point CAL3106:

**X1: 283262.665 Y1: 4455134.453 Reason For Exclusion: Obscure Location**

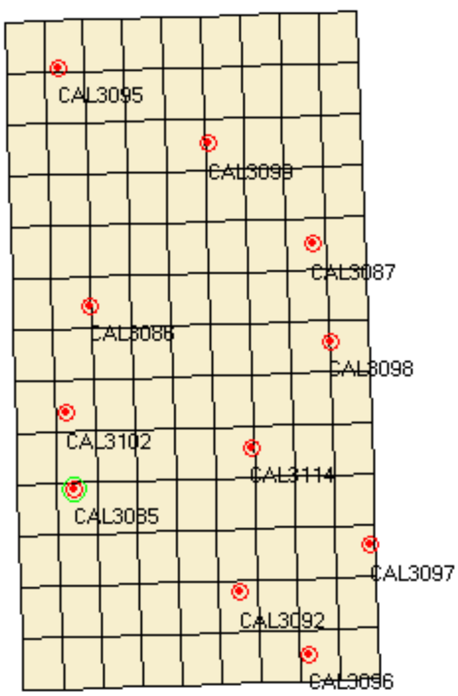
## Project Information

Prepared By: JG
Project Name: Nebraska 60cm
Sensor Info: ADS100
Sensor Resolution: 0.6
Vendor Name: Merrick-Surdex JV
Date of Aquisition: Start: 8/6/2018 Finish: 8/6/2018

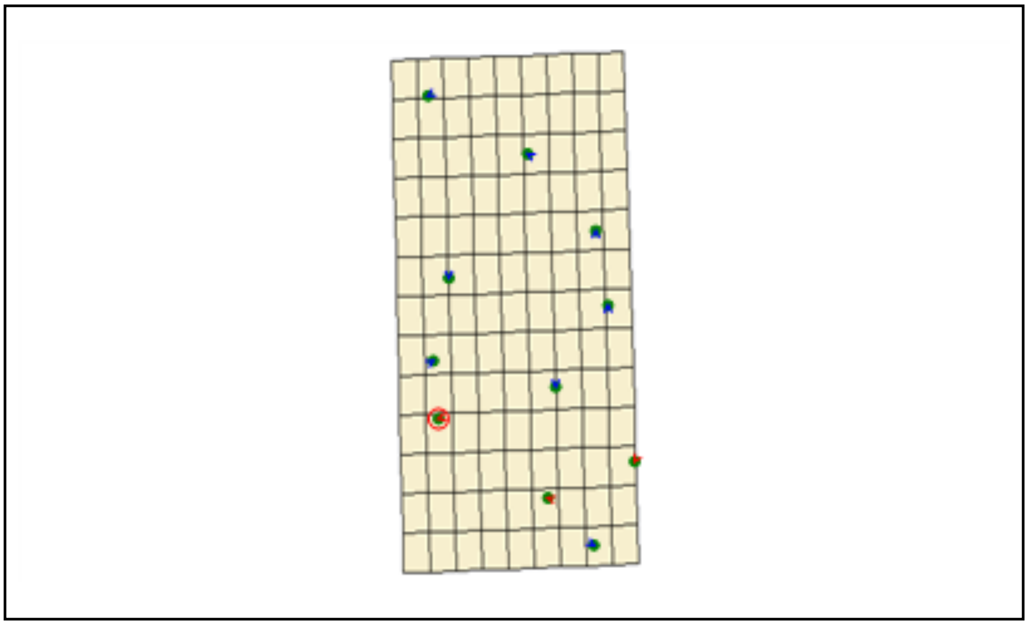
## Metadata Information

Index File Name: SE_Block_doqqs_UTM14.shp
# of Polygons: 117
# of Matching Images: 117
Polygon ID: Name
Units: Meters
Image Folder Path: I:\2800105\product_tiles\Client_SE_UTM14_hr4\Delivery\2018-08-03_112441
Threshold: CE90: 0.427
Scaling Used: 1:900

## Tiled-Image Area

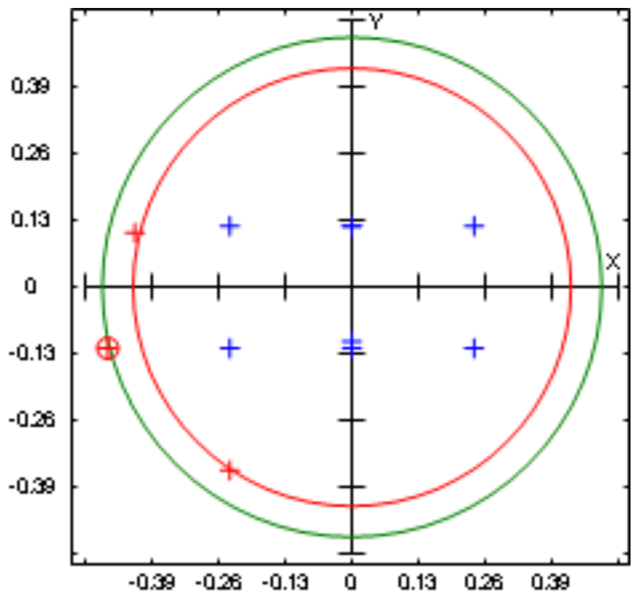


## Vector Offset



Scaling Factor: 200

## Circular Error




## Error Statistics

| | | | |
|---|---|---|---|
| Min ΔX: | -0.476 | CE 95: | 0.487 |
| Min ΔY: | -0.357 | Skew ΔX: | -0.069 |
| Max ΔX: | 0.238 | Skew ΔY: | -0.632 |
| Max ΔY: | 0.119 | Horiz. Bias: | 0.108 |
| Mean ΔX: | -0.103 | SRMSE H: | 0.06 |
| Mean ΔY: | -0.032 | CI: | 0.118 |
| RmseX: | 0.25 | | |
| RmseY: | 0.155 | | |
| RmseH: | 0.294 | | |
| NSSDA: | 0.509 | | |
| No. Obs.: | 11 | | |
| SX: | 0.239 | | |
| SY: | 0.159 | | |
| SH: | 0.199 | | |
| CE 90: | 0.427 | | |

## Coordinates and Offsets of Analyzed Locations

| | | ID | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | **Survey X** | **Survey Y** | **Photo X** | **Photo Y** | **ΔX** | **ΔY** |
| 1) | ☑ | **CAL3086** | | | | | | |
| | | | 722338.72 | 4482676.762 | 722338.717 | 4482676.656 | 0 | -0.106 |
| 2) | ☑ | **CAL3102** | | | | | | |
| | | | 719158.68 | 4468119.691 | 719158.916 | 4468119.81 | 0.238 | 0.119 |
| 3) | ☑ | **CAL3114** | | | | | | |
| | | | 744079.73 | 4463539.449 | 744079.729 | 4463539.33 | 0 | -0.119 |
| 4) | ☑ | **CAL3098** | | | | | | |
| | | | 754741.01 | 4477877.984 | 754741.01 | 4477878.103 | 0 | 0.119 |
| 5) | ☑ | **CAL3087** | | | | | | |
| | | | 752232.34 | 4490996.408 | 752232.338 | 4490996.527 | 0 | 0.119 |
| 6) | ☑ | **CAL3095** | | | | | | |
| | | | 718103.42 | 4514727.992 | 718103.177 | 4514727.873 | -0.238 | -0.119 |
| 7) | ☑ | **CAL3099** | | | | | | |
| | | | 738395.32 | 4504515.557 | 738395.079 | 4504515.676 | -0.238 | 0.119 |
| 8) | ☑ | **CAL3085** | | | | | | |
| | | | 720231.64 | 4457919.89 | 720231.163 | 4457919.771 | -0.476 | -0.119 |
| 9) | ☑ | **CAL3092** | | | | | | |
| | | | 742523.22 | 4444000.589 | 742522.799 | 4444000.695 | -0.423 | 0.106 |
| 10) | ☑ | **CAL3096** | | | | | | |
| | | | 751876.59 | 4435650.717 | 751876.823 | 4435650.598 | 0.238 | -0.119 |

| | ID | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Survey X | Survey Y | Photo X | Photo Y | ΔX | ΔY |
| 11) ☑ | CAL3097 | | | | | | |
| | | 760172.317 | 4450406.491 | 760172.079 | 4450406.134 | -0.238 | -0.357 |

## Point CAL3086:

**X1: 722338.717** **Y1: 4482676.762** **X2: 722338.717** **Y2: 4482676.656** **Delta X: 0** **Delta Y: -0.106**


## Point CAL3102:

**X1: 719158.678** **Y1: 4468119.691** **X2: 719158.916** **Y2: 4468119.81** **Delta X: 0.238** **Delta Y: 0.119**

## Point CAL3114:

**X1: 744079.729 Y1: 4463539.449 X2: 744079.729 Y2: 4463539.33 Delta X: 0 Delta Y: -0.119**


## Point CAL3098:

**X1: 754741.01 Y1: 4477877.984 X2: 754741.01 Y2: 4477878.103 Delta X: 0 Delta Y: 0.119**

## Point CAL3087:

**X1: 752232.338 Y1: 4490996.408 X2: 752232.338 Y2: 4490996.527 Delta X: 0 Delta Y: 0.119**


## Point CAL3095:

**X1: 718103.415 Y1: 4514727.992 X2: 718103.177 Y2: 4514727.873 Delta X: -0.238 Delta Y: -0.119**

**Point CAL3099:**

**X1: 738395.317** **Y1: 4504515.557** **X2: 738395.079** **Y2: 4504515.676** **Delta X: -0.238** **Delta Y: 0.119**


**Point CAL3085:**

**X1: 720231.639** **Y1: 4457919.89** **X2: 720231.163** **Y2: 4457919.771** **Delta X: -0.476** **Delta Y: -0.119**

## Point CAL3092:

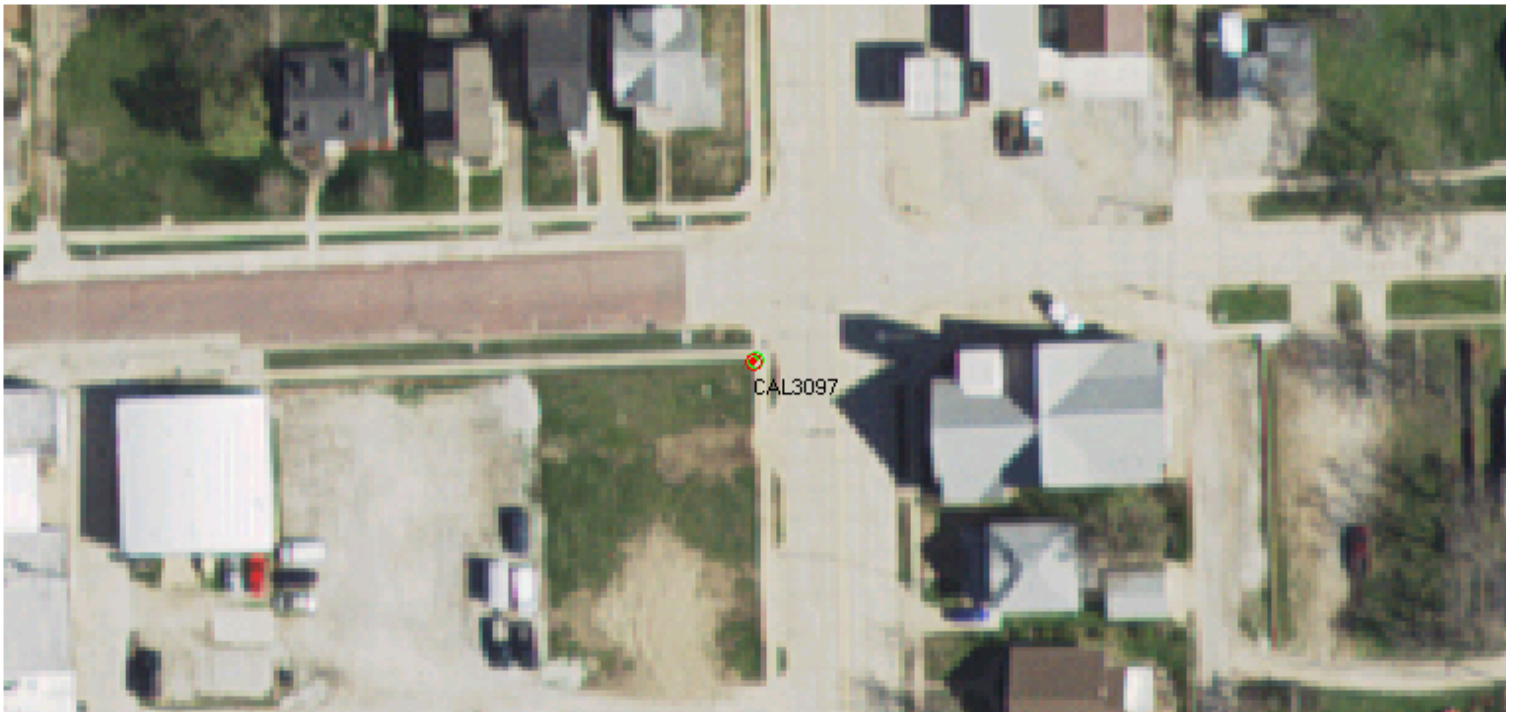
**X1: 742523.222** **Y1: 4444000.589** **X2: 742522.799** **Y2: 4444000.695** **Delta X: -0.423** **Delta Y: 0.106**


## Point CAL3096:

**X1: 751876.585** **Y1: 4435650.717** **X2: 751876.823** **Y2: 4435650.598** **Delta X: 0.238** **Delta Y: -0.119**

## Point CAL3097:

**X1: 760172.317 Y1: 4450406.491 X2: 760172.079 Y2: 4450406.134 Delta X: -0.238 Delta Y: -0.357**



## Coordinates and Offsets of Unanalyzed Locations

| | | ID | | | |
|---|---|---|---|---|---|
| | | | Survey X | Survey Y | Reason For Exclusion |
| 1) | ☐ | **CAL3100** | | | |
| | | | 738178.864 | 4515804.218 | Ambigious Location |
| 2) | ☐ | **CAL3105** | | | |
| | | | 752777.065 | 4512687.947 | Ambigious Location |
| 3) | ☐ | **CAL3112** | | | |
| | | | 729278.003 | 4489318.046 | Ambigious Location |
| 4) | ☐ | **CAL3107** | | | |
| | | | 719565.347 | 4435887.619 | Ambigious Location |

## Point CAL3100:

**X1: 738178.864 Y1: 4515804.218 Reason For Exclusion: Ambigious Location**

## Point CAL3105:

**X1: 752777.065 Y1: 4512687.947 Reason For Exclusion: Ambigious Location**

## Point CAL3112:

**X1: 729278.003 Y1: 4489318.046 Reason For Exclusion: Ambigious Location**

## Point CAL3107:

**X1: 719565.347 Y1: 4435887.619 Reason For Exclusion: Ambigious Location**

MERRICK SURDEX JOINT VENTURE

CompassAA™

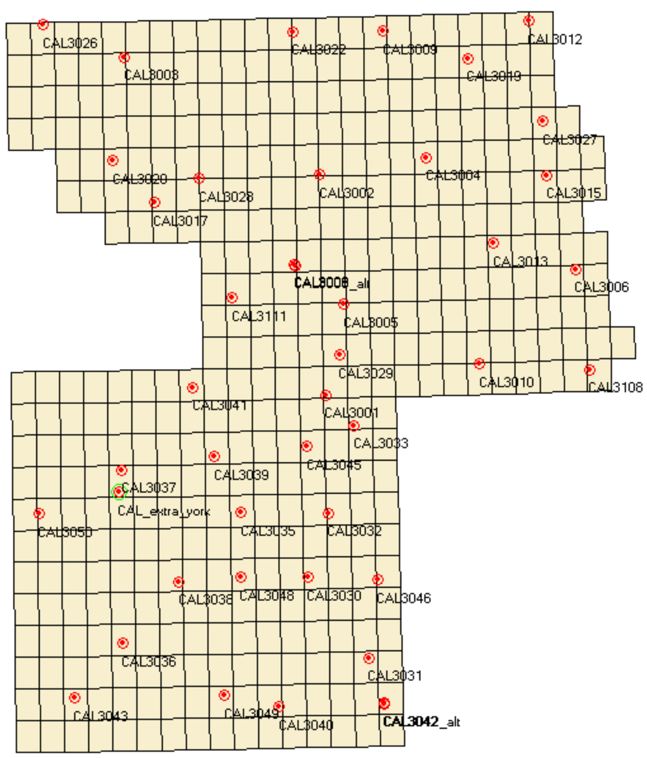
## Project Information

Prepared By: JG
Project Name: Nebraska 60cm Block 3 and 4
Sensor Info: ADS100
Sensor Resolution: 0.6
Vendor Name: Merrick-Surdex JV
Date of Aquisition: Start: 12/7/2018 Finish: 12/7/2018

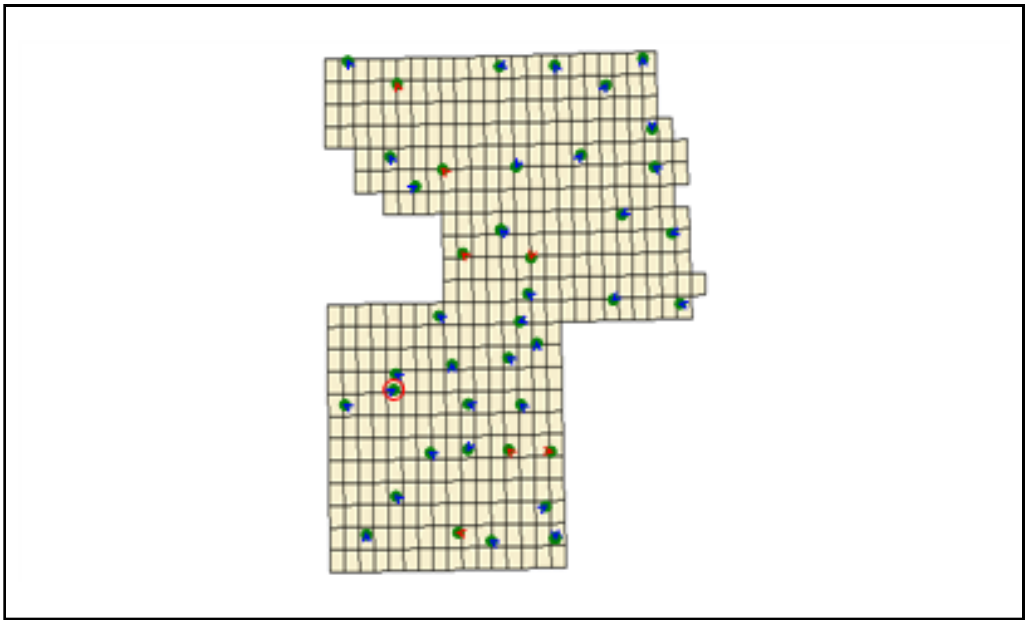
## Metadata Information

Index File Name: Blk3_4_UTM14_AA.shp
# of Polygons: 429
# of Matching Images: 429
Polygon ID: Name
Units: Meters
Image Folder Path: I:\2800105\product_tiles\Client_NW_UTM14_hr4\Delivery\2018-11-26_101001
Threshold: CE90: 0.385
Scaling Used: 1:650

## Tiled-Image Area

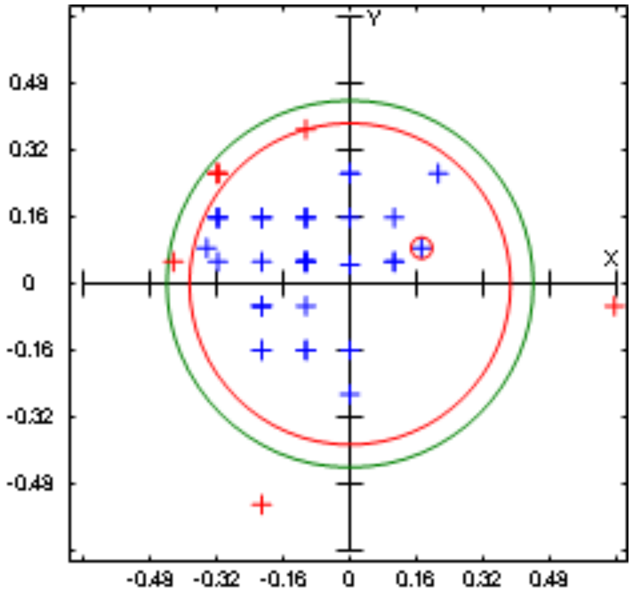


## Vector Offset



Scaling Factor: 200

## Circular Error




## Error Statistics

| | | | |
|---|---|---|---|
| Min ΔX: | -0.423 | CE 95: | 0.44 |
| Min ΔY: | -0.529 | Skew ΔX: | 1.557 |
| Max ΔX: | 0.635 | Skew ΔY: | -1.059 |
| Max ΔY: | 0.37 | Horiz. Bias: | 0.132 |
| Mean ΔX: | -0.117 | SRMSE H: | 0.027 |
| Mean ΔY: | 0.06 | CI: | 0.054 |
| RmseX: | 0.221 | | |
| RmseY: | 0.178 | | |
| RmseH: | 0.284 | | |
| NSSDA: | 0.491 | | |
| No. Obs.: | 43 | | |
| SX: | 0.189 | | |
| SY: | 0.17 | | |
| SH: | 0.18 | | |
| CE 90: | 0.385 | | |

## Coordinates and Offsets of Analyzed Locations

| | ID | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Survey X | Survey Y | Photo X | Photo Y | ΔX | ΔY |
| 1) ☑ | CAL3005 | | | | | | |
| | | 667416.8 | 4561114.577 | 667416.589 | 4561114.048 | -0.212 | -0.529 |
| 2) ☑ | CAL3008 | | | | | | |
| | | 656594.84 | 4569821.799 | 656594.494 | 4569821.885 | -0.344 | 0.086 |
| 3) ☑ | CAL3008_alt | | | | | | |
| | | 656664.51 | 4569600.391 | 656664.293 | 4569600.55 | -0.212 | 0.159 |
| 4) ☑ | CAL3029 | | | | | | |
| | | 666340.05 | 4549967.753 | 666339.733 | 4549967.912 | -0.318 | 0.159 |
| 5) ☑ | CAL3111 | | | | | | |
| | | 642965.79 | 4562472.168 | 642965.468 | 4562472.433 | -0.318 | 0.265 |
| 6) ☑ | CAL3002 | | | | | | |
| | | 662080.93 | 4589443.538 | 662080.826 | 4589443.379 | -0.106 | -0.159 |
| 7) ☑ | CAL3022 | | | | | | |
| | | 656077.24 | 4620664.619 | 656077.028 | 4620664.566 | -0.212 | -0.053 |
| 8) ☑ | CAL3004 | | | | | | |
| | | 685381.92 | 4593165.005 | 685382.135 | 4593165.27 | 0.212 | 0.265 |
| 9) ☑ | CAL3009 | | | | | | |
| | | 675961.59 | 4620917.03 | 675961.483 | 4620917.189 | -0.106 | 0.159 |
| 10) ☑ | CAL3012 | | | | | | |
| | | 707732.24 | 4623144.461 | 707732.237 | 4623144.507 | 0 | 0.046 |

| | ID | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Survey X | Survey Y | Photo X | Photo Y | ΔX | ΔY |
| 11) | ☑ | CAL3015 | | | | | |
| | | 711868.624 | 4589352.769 | 711868.518 | 4589352.822 | -0.106 | 0.053 |
| 12) | ☑ | CAL3019 | | | | | |
| | | 694412.965 | 4614849.195 | 694413.071 | 4614849.354 | 0.106 | 0.159 |
| 13) | ☑ | CAL3027 | | | | | |
| | | 711004.609 | 4601199.272 | 711004.609 | 4601199.007 | 0 | -0.265 |
| 14) | ☑ | CAL3036 | | | | | |
| | | 618909.943 | 4486894.638 | 618909.731 | 4486894.797 | -0.212 | 0.159 |
| 15) | ☑ | CAL3038 | | | | | |
| | | 631286.863 | 4500427.906 | 631286.545 | 4500428.065 | -0.318 | 0.159 |
| 16) | ☑ | CAL3043 | | | | | |
| | | 608299.548 | 4474970.732 | 608299.548 | 4474970.997 | 0 | 0.265 |
| 17) | ☑ | CAL3003 | | | | | |
| | | 619281.234 | 4615177.049 | 619281.128 | 4615177.419 | -0.106 | 0.37 |
| 18) | ☑ | CAL3017 | | | | | |
| | | 625892.02 | 4583313.994 | 625892.126 | 4583314.047 | 0.106 | 0.053 |
| 19) | ☑ | CAL3020 | | | | | |
| | | 616766.884 | 4592552.447 | 616766.778 | 4592552.606 | -0.106 | 0.159 |
| 20) | ☑ | CAL3026 | | | | | |
| | | 601557.018 | 4622203.87 | 601556.912 | 4622204.029 | -0.106 | 0.159 |

| | ID | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Survey X | Survey Y | Photo X | Photo Y | ΔX | ΔY |
| 21) | ☑ | CAL3028 | | | | | |
| | | 635731.749 | 4588623.154 | 635731.431 | 4588623.419 | -0.318 | 0.265 |
| 22) | ☑ | CAL3030 | | | | | |
| | | 659407.143 | 4501386.554 | 659406.825 | 4501386.819 | -0.318 | 0.265 |
| 23) | ☑ | CAL3031 | | | | | |
| | | 672737.85 | 4483712.205 | 672737.956 | 4483712.258 | 0.106 | 0.053 |
| 24) | ☑ | CAL3040 | | | | | |
| | | 653205.702 | 4473009.202 | 653205.596 | 4473009.255 | -0.106 | 0.053 |
| 25) | ☑ | CAL3042 | | | | | |
| | | 676070.544 | 4473810.558 | 676070.332 | 4473810.399 | -0.212 | -0.159 |
| 26) | ☑ | CAL3042_alt | | | | | |
| | | 676277.753 | 4473841.213 | 676277.753 | 4473841.054 | 0 | -0.159 |
| 27) | ☑ | CAL3046 | | | | | |
| | | 674675.309 | 4500835.445 | 674675.944 | 4500835.392 | 0.635 | -0.053 |
| 28) | ☑ | CAL3048 | | | | | |
| | | 644755.545 | 4501424.085 | 644755.439 | 4501423.926 | -0.106 | -0.159 |
| 29) | ☑ | CAL3049 | | | | | |
| | | 641266.292 | 4475585.445 | 641265.869 | 4475585.498 | -0.423 | 0.053 |
| 30) | ☑ | CAL3006 | | | | | |
| | | 718101.445 | 4568714.486 | 718101.233 | 4568714.433 | -0.212 | -0.053 |

| | ID | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Survey X | Survey Y | Photo X | Photo Y | ΔX | ΔY |
| 31) ☑ | CAL3010 | | | | | | |
| | | 697061.77 | 4548048.91 | 697061.558 | 4548048.751 | -0.212 | -0.159 |
| 32) ☑ | CAL3013 | | | | | | |
| | | 700221.22 | 4574515.918 | 700221.114 | 4574515.865 | -0.106 | -0.053 |
| 33) ☑ | CAL3108 | | | | | | |
| | | 721186.751 | 4546793.916 | 721186.433 | 4546793.969 | -0.318 | 0.053 |
| 34) ☑ | CAL3001 | | | | | | |
| | | 663378.608 | 4541263.909 | 663378.396 | 4541263.856 | -0.212 | -0.053 |
| 35) ☑ | CAL3032 | | | | | | |
| | | 663876.835 | 4515409.457 | 663876.623 | 4515409.616 | -0.212 | 0.159 |
| 36) ☑ | CAL3033 | | | | | | |
| | | 669593.297 | 4534555.984 | 669593.297 | 4534556.143 | 0 | 0.159 |
| 37) ☑ | CAL3035 | | | | | | |
| | | 644937.607 | 4515595.32 | 644937.395 | 4515595.373 | -0.212 | 0.053 |
| 38) ☑ | CAL3039 | | | | | | |
| | | 639062.755 | 4527803.941 | 639062.755 | 4527804.206 | 0 | 0.265 |
| 39) ☑ | CAL3045 | | | | | | |
| | | 659294.224 | 4529996.02 | 659294.118 | 4529996.073 | -0.106 | 0.053 |
| 40) ☑ | CAL3037 | | | | | | |
| | | 618781.515 | 4524927.766 | 618781.409 | 4524927.819 | -0.106 | 0.053 |

|  | ID |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|
|  |  |  | Survey X | Survey Y | Photo X | Photo Y | ΔX | ΔY |
| 41) | ☑ | CAL3041 |  |  |  |  |  |  |
|  |  |  | 634339.585 | 4542991.279 | 634339.267 | 4542991.438 | -0.318 | 0.159 |
| 42) | ☑ | CAL3050 |  |  |  |  |  |  |
|  |  |  | 600553.467 | 4515315.223 | 600553.361 | 4515315.276 | -0.106 | 0.053 |
| 43) | ☑ | CAL_extra_york |  |  |  |  |  |  |
|  |  |  | 618095.128 | 4520039.281 | 618095.3 | 4520039.367 | 0.172 | 0.086 |

## Point CAL3005:

**X1: 667416.801 Y1: 4561114.577 X2: 667416.589 Y2: 4561114.048 Delta X: -0.212 Delta Y: -0.529**


## Point CAL3008:

**X1: 656594.838 Y1: 4569821.799 X2: 656594.494 Y2: 4569821.885 Delta X: -0.344 Delta Y: 0.086**

## Point CAL3008_alt:

**X1: 656664.505 Y1: 4569600.391 X2: 656664.293 Y2: 4569600.55 Delta X: -0.212 Delta Y: 0.159**


## Point CAL3029:

**X1: 666340.051 Y1: 4549967.753 X2: 666339.733 Y2: 4549967.912 Delta X: -0.318 Delta Y: 0.159**

## Point CAL3111:

**X1: 642965.786** **Y1: 4562472.168** **X2: 642965.468** **Y2: 4562472.433** **Delta X: -0.318** **Delta Y: 0.265**


## Point CAL3002:

**X1: 662080.932** **Y1: 4589443.538** **X2: 662080.826** **Y2: 4589443.379** **Delta X: -0.106** **Delta Y: -0.159**

## Point CAL3022:

**X1: 656077.24 Y1: 4620664.619 X2: 656077.028 Y2: 4620664.566 Delta X: -0.212 Delta Y: -0.053**


## Point CAL3004:

**X1: 685381.923 Y1: 4593165.005 X2: 685382.135 Y2: 4593165.27 Delta X: 0.212 Delta Y: 0.265**

## Point CAL3009:

**X1: 675961.589 Y1: 4620917.03 X2: 675961.483 Y2: 4620917.189 Delta X: -0.106 Delta Y: 0.159**


## Point CAL3012:

**X1: 707732.237 Y1: 4623144.461 X2: 707732.237 Y2: 4623144.507 Delta X: 0 Delta Y: 0.046**

## Point CAL3015:

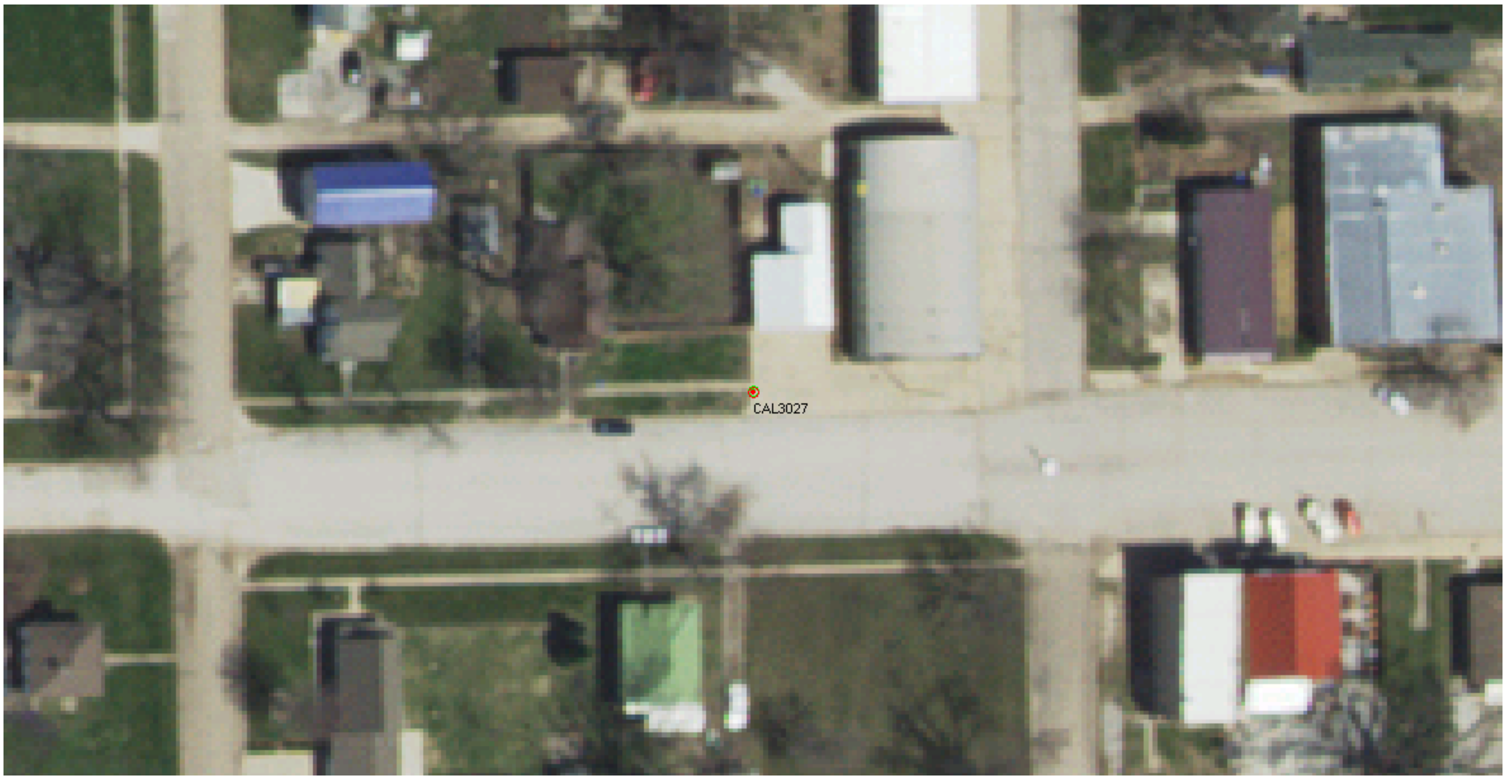
**X1: 711868.624 Y1: 4589352.769 X2: 711868.518 Y2: 4589352.822 Delta X: -0.106 Delta Y: 0.053**


## Point CAL3019:

**X1: 694412.965 Y1: 4614849.195 X2: 694413.071 Y2: 4614849.354 Delta X: 0.106 Delta Y: 0.159**

## Point CAL3027:

**X1: 711004.609 Y1: 4601199.272 X2: 711004.609 Y2: 4601199.007 Delta X: 0 Delta Y: -0.265**




## Point CAL3036:

**X1: 618909.943 Y1: 4486894.638 X2: 618909.731 Y2: 4486894.797 Delta X: -0.212 Delta Y: 0.159**

## Point CAL3038:

**X1: 631286.863** **Y1: 4500427.906** **X2: 631286.545** **Y2: 4500428.065** **Delta X: -0.318** **Delta Y: 0.159**


## Point CAL3043:

**X1: 608299.548** **Y1: 4474970.732** **X2: 608299.548** **Y2: 4474970.997** **Delta X: 0** **Delta Y: 0.265**

## Point CAL3003:

**X1: 619281.234 Y1: 4615177.049 X2: 619281.128 Y2: 4615177.419 Delta X: -0.106 Delta Y: 0.37**


## Point CAL3017:

**X1: 625892.02 Y1: 4583313.994 X2: 625892.126 Y2: 4583314.047 Delta X: 0.106 Delta Y: 0.053**

## Point CAL3020:

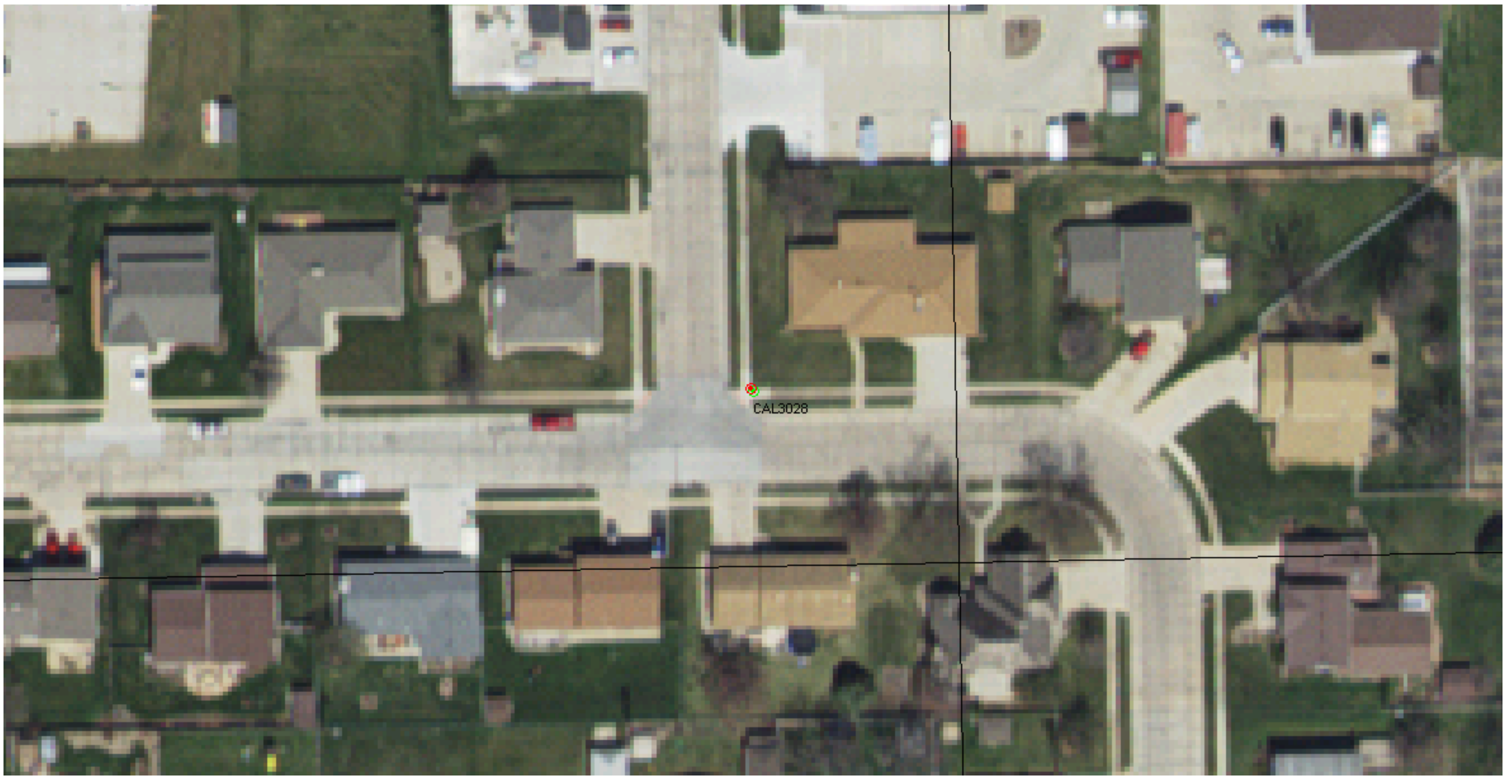
**X1: 616766.884 Y1: 4592552.447 X2: 616766.778 Y2: 4592552.606 Delta X: -0.106 Delta Y: 0.159**


## Point CAL3026:

**X1: 601557.018 Y1: 4622203.87 X2: 601556.912 Y2: 4622204.029 Delta X: -0.106 Delta Y: 0.159**

## Point CAL3028:

**X1: 635731.749** **Y1: 4588623.154** **X2: 635731.431** **Y2: 4588623.419** **Delta X: -0.318** **Delta Y: 0.265**




## Point CAL3030:

**X1: 659407.143** **Y1: 4501386.554** **X2: 659406.825** **Y2: 4501386.819** **Delta X: -0.318** **Delta Y: 0.265**

## Point CAL3031:

**X1: 672737.85 Y1: 4483712.205 X2: 672737.956 Y2: 4483712.258 Delta X: 0.106 Delta Y: 0.053**


## Point CAL3040:

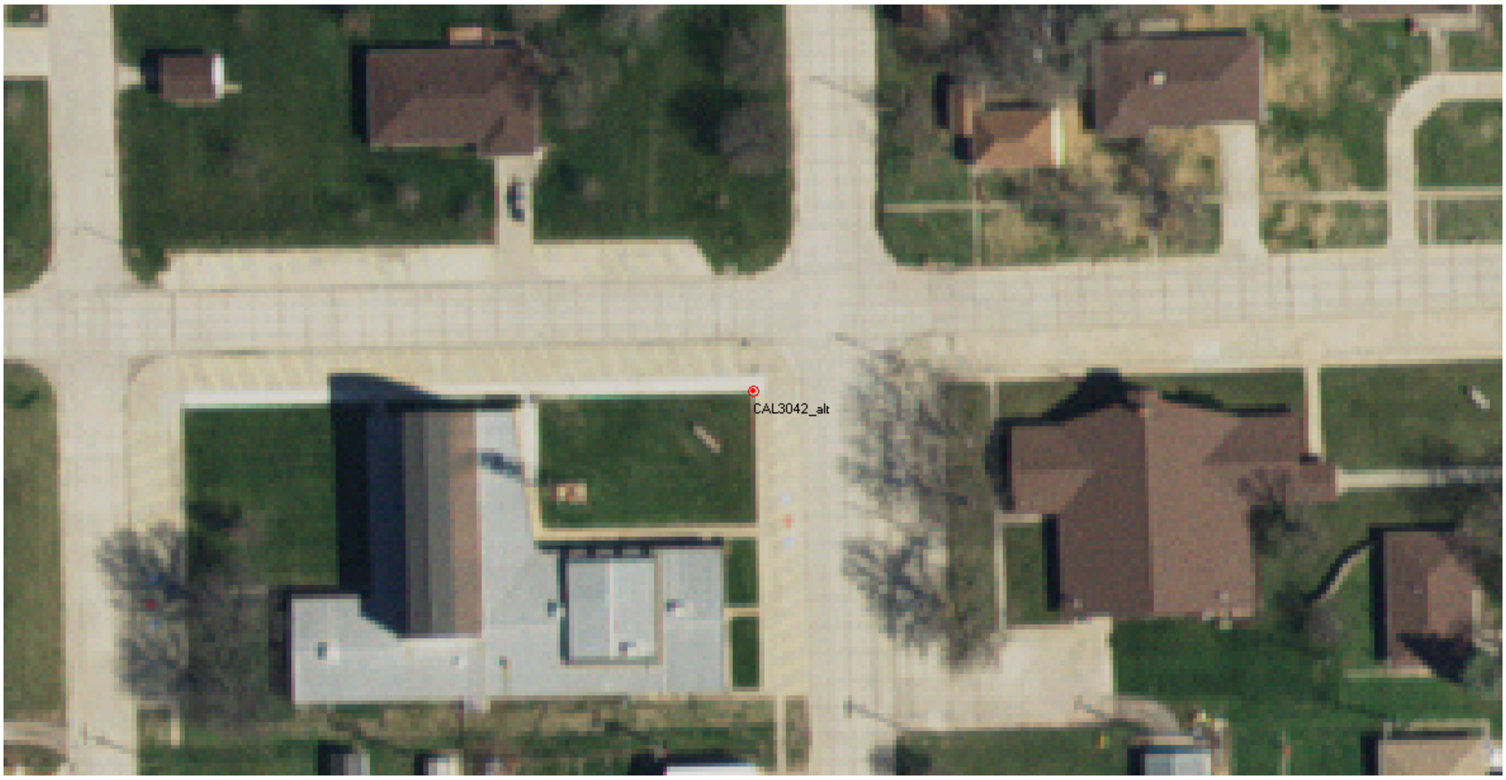
**X1: 653205.702 Y1: 4473009.202 X2: 653205.596 Y2: 4473009.255 Delta X: -0.106 Delta Y: 0.053**

## Point CAL3042:

**X1: 676070.544 Y1: 4473810.558 X2: 676070.332 Y2: 4473810.399 Delta X: -0.212 Delta Y: -0.159**


## Point CAL3042_alt:

**X1: 676277.753 Y1: 4473841.213 X2: 676277.753 Y2: 4473841.054 Delta X: 0 Delta Y: -0.159**



## Point CAL3046:

**X1: 674675.309  Y1: 4500835.445  X2: 674675.944  Y2: 4500835.392  Delta X: 0.635  Delta Y: -0.053**


## Point CAL3048:

**X1: 644755.545  Y1: 4501424.085  X2: 644755.439  Y2: 4501423.926  Delta X: -0.106  Delta Y: -0.159**

## Point CAL3049:

**X1: 641266.292 Y1: 4475585.445 X2: 641265.869 Y2: 4475585.498 Delta X: -0.423 Delta Y: 0.053**


## Point CAL3006:

**X1: 718101.445 Y1: 4568714.486 X2: 718101.233 Y2: 4568714.433 Delta X: -0.212 Delta Y: -0.053**

## Point CAL3010:

**X1: 697061.77** **Y1: 4548048.91** **X2: 697061.558** **Y2: 4548048.751** **Delta X: -0.212** **Delta Y: -0.159**


## Point CAL3013:

**X1: 700221.22** **Y1: 4574515.918** **X2: 700221.114** **Y2: 4574515.865** **Delta X: -0.106** **Delta Y: -0.053**

**Point CAL3108:**

**X1: 721186.751** **Y1: 4546793.916** **X2: 721186.433** **Y2: 4546793.969** **Delta X: -0.318** **Delta Y: 0.053**


**Point CAL3001:**

**X1: 663378.608** **Y1: 4541263.909** **X2: 663378.396** **Y2: 4541263.856** **Delta X: -0.212** **Delta Y: -0.053**

## Point CAL3032:

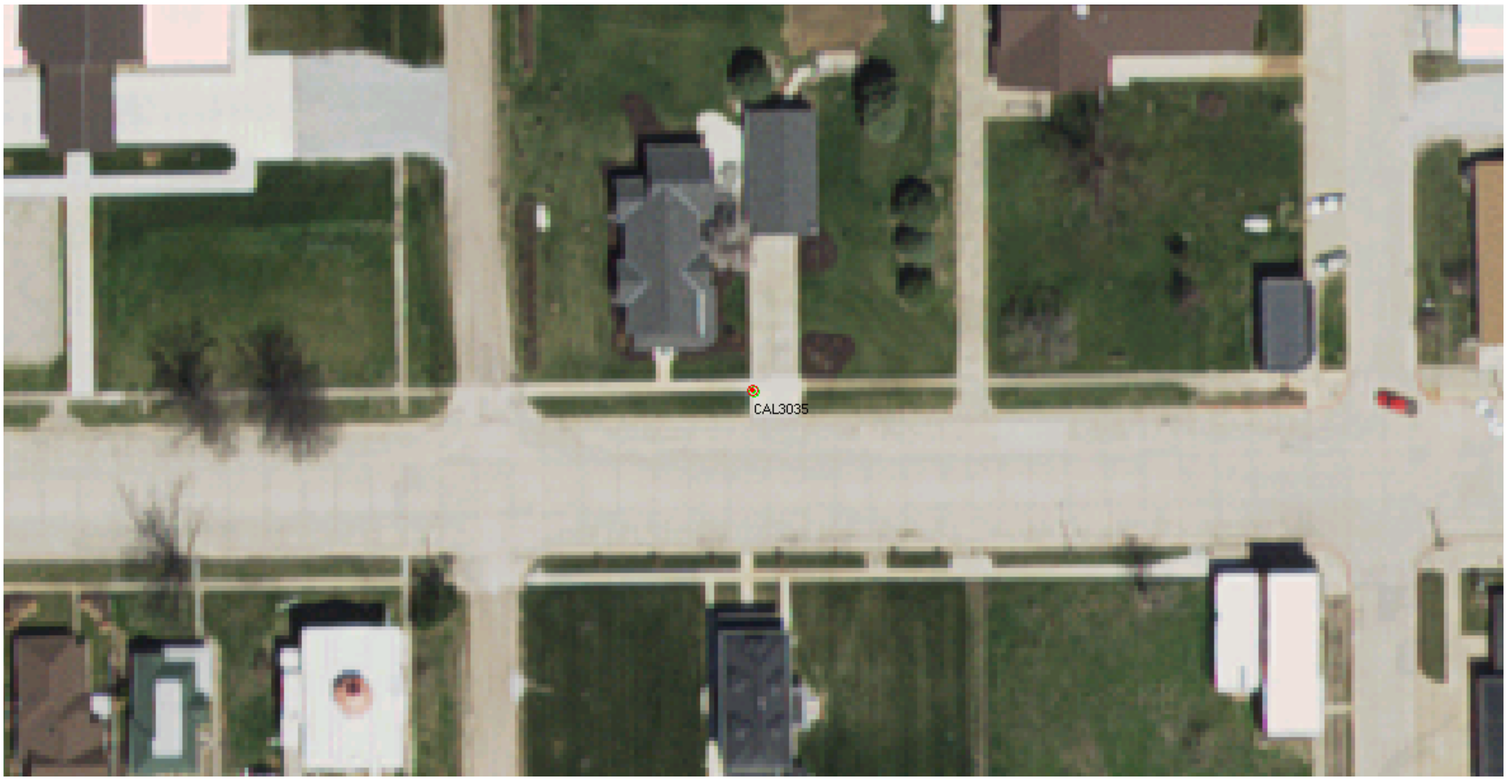
**X1: 663876.835 Y1: 4515409.457 X2: 663876.623 Y2: 4515409.616 Delta X: -0.212 Delta Y: 0.159**


## Point CAL3033:

**X1: 669593.297 Y1: 4534555.984 X2: 669593.297 Y2: 4534556.143 Delta X: 0 Delta Y: 0.159**

## Point CAL3035:

**X1: 644937.607 Y1: 4515595.32 X2: 644937.395 Y2: 4515595.373 Delta X: -0.212 Delta Y: 0.053**




## Point CAL3039:

**X1: 639062.755 Y1: 4527803.941 X2: 639062.755 Y2: 4527804.206 Delta X: 0 Delta Y: 0.265**

## Point CAL3045:

**X1: 659294.224 Y1: 4529996.02 X2: 659294.118 Y2: 4529996.073 Delta X: -0.106 Delta Y: 0.053**


## Point CAL3037:

**X1: 618781.515 Y1: 4524927.766 X2: 618781.409 Y2: 4524927.819 Delta X: -0.106 Delta Y: 0.053**

## Point CAL3041:

**X1: 634339.585 Y1: 4542991.279 X2: 634339.267 Y2: 4542991.438 Delta X: -0.318 Delta Y: 0.159**


## Point CAL3050:

**X1: 600553.467 Y1: 4515315.223 X2: 600553.361 Y2: 4515315.276 Delta X: -0.106 Delta Y: 0.053**

## Point CAL_extra_york:

**X1: 618095.128 Y1: 4520039.281 X2: 618095.3 Y2: 4520039.367 Delta X: 0.172 Delta Y: 0.086**

## Coordinates and Offsets of Unanalyzed Locations

| | | ID | | | |
|---|---|---|---|---|---|
| | | | Survey X | Survey Y | Reason For Exclusion |
| 1) | ☐ | CAL3007 | | | |
| | | | 674516.863 | 4607206.849 | Ambigious Location |
| 2) | ☐ | CAL3021 | | | |
| | | | 649077.179 | 4595420.032 | Ambigious Location |
| 3) | ☐ | CAL_COLFAX_EXTRA | | | |
| | | | 661773.175 | 4605319.462 | Ambigious Location |
| 4) | ☐ | CAL_DODGE_EXTRA | | | |
| | | | 691568.236 | 4601962.038 | Ambigious Location |
| 5) | ☐ | CAL3034 | | | |
| | | | 606065.813 | 4486732.136 | Ambigious Location |
| 6) | ☐ | CAL3047 | | | |
| | | | 602684.937 | 4498013.685 | Ambigious Location |
| 7) | ☐ | CAL3051 | | | |
| | | | 620768.091 | 4469251.703 | Ambigious Location |
| 8) | ☐ | CAL3011 | | | |
| | | | 640599.128 | 4616203.153 | Ambigious Location |
| 9) | ☐ | CAL3024 | | | |
| | | | 608607.956 | 4605992.393 | Ambigious Location |
| 10) | ☐ | CAL_extra_platte | | | |
| | | | 627728.172 | 4620847.869 | Ambigious Location |

## Coordinates and Offsets of Unanalyzed Locations

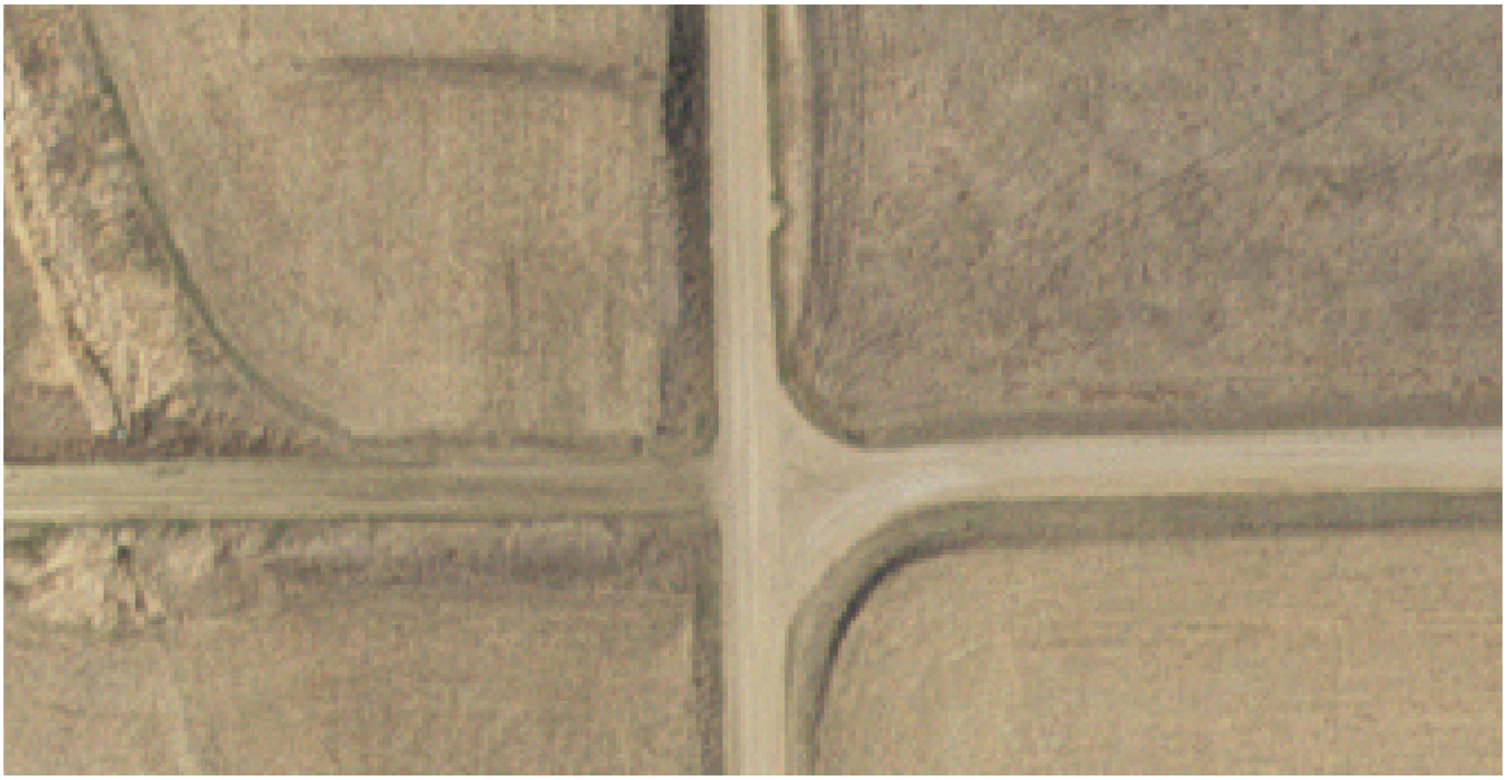
| | | ID | | | |
|---|---|---|---|---|---|
| | | | Survey X | Survey Y | Reason For Exclusion |
| 11) | ☐ | **CAL3049_alt** | 709818.31 | | |
| | | | | 4548392.541 | Ambigious Location |
| 12) | ☐ | **CAL3014** | 716114.571 | | |
| | | | | 4555022.368 | Ambigious Location |
| 13) | ☐ | **CAL3016** | 686063.094 | | |
| | | | | 4583287.547 | Ambigious Location |
| 14) | ☐ | **CAL3023** | 685121.847 | | |
| | | | | 4559104.39 | Ambigious Location |
| 15) | ☐ | **CAL3025** | 698593.744 | | |
| | | | | 4561103.559 | Ambigious Location |
| 16) | ☐ | **CAL_EXTRA_SAL** | 638734.138 | | |
| | | | | 4545279.45 | Ambigious Location |
| 17) | ☐ | **CAL3018** | 650794.425 | | |
| | | | | 4545481.826 | Ambigious Location |
| 18) | ☐ | **CAL3109** | 673978.234 | | |
| | | | | 4545941.814 | Ambigious Location |
| 19) | ☐ | **CAL3110** | 674268.027 | | |
| | | | | 4534671.783 | Ambigious Location |
| 20) | ☐ | **CAL_extra_sew** | 606704.677 | | |
| | | | | 4539866.952 | Ambigious Location |

## Coordinates and Offsets of Unanalyzed Locations

| | ID | | | |
|---|---|---|---|---|
| | | Survey X | Survey Y | Reason For Exclusion |
| 21) ☐ | CAL3044 | | | |
| | | 606704.677 | 4539866.952 | Ambigious Location |

## Point CAL3007:

**X1: 674516.863 Y1: 4607206.849 Reason For Exclusion: Ambigious Location**



## Point CAL3021:

**X1: 649077.179 Y1: 4595420.032 Reason For Exclusion: Ambigious Location**

## Point CAL_COLFAX_EXTRA:

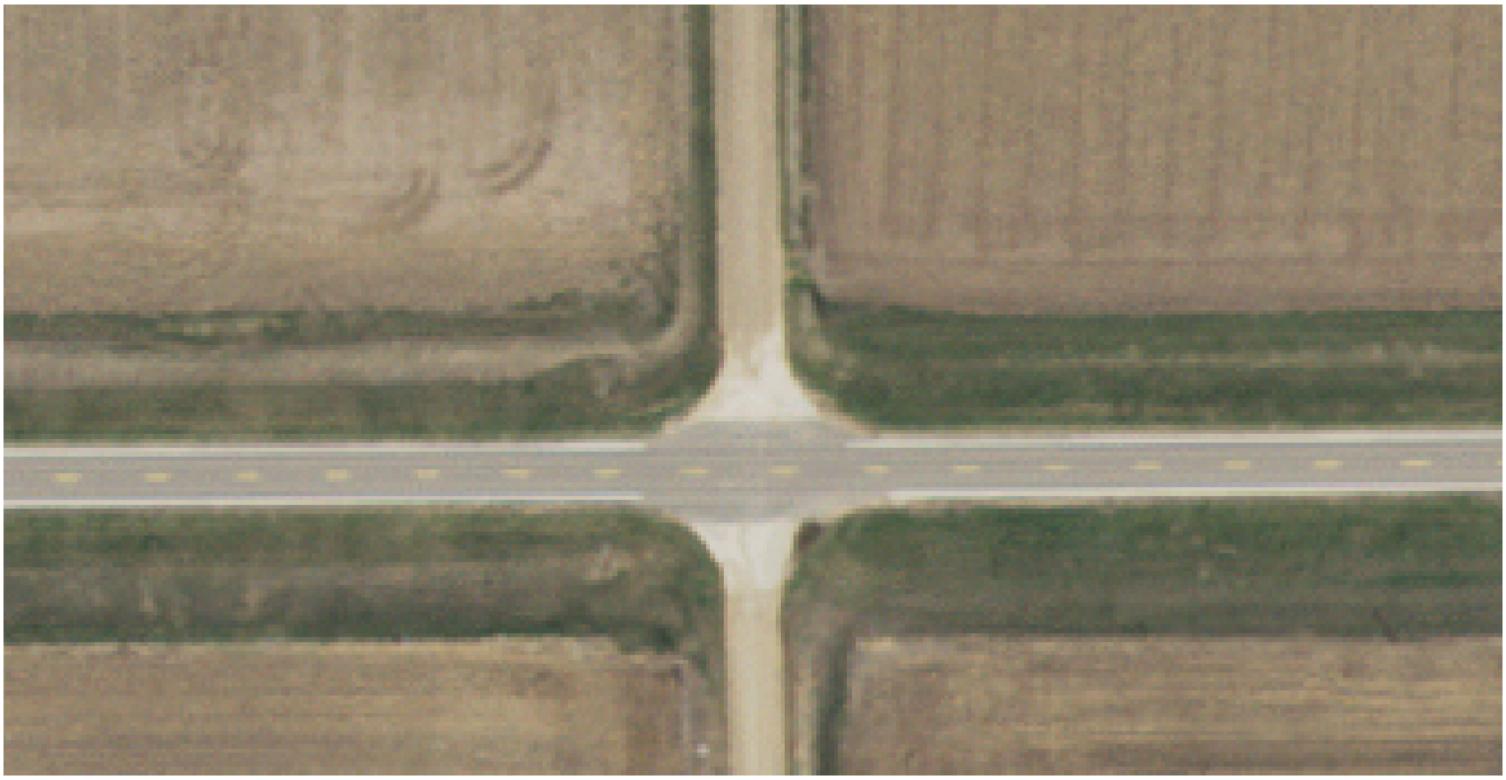
**X1: 661773.175 Y1: 4605319.462 Reason For Exclusion: Ambigious Location**

## Point CAL_DODGE_EXTRA:

**X1: 691568.236 Y1: 4601962.038 Reason For Exclusion: Ambigious Location**

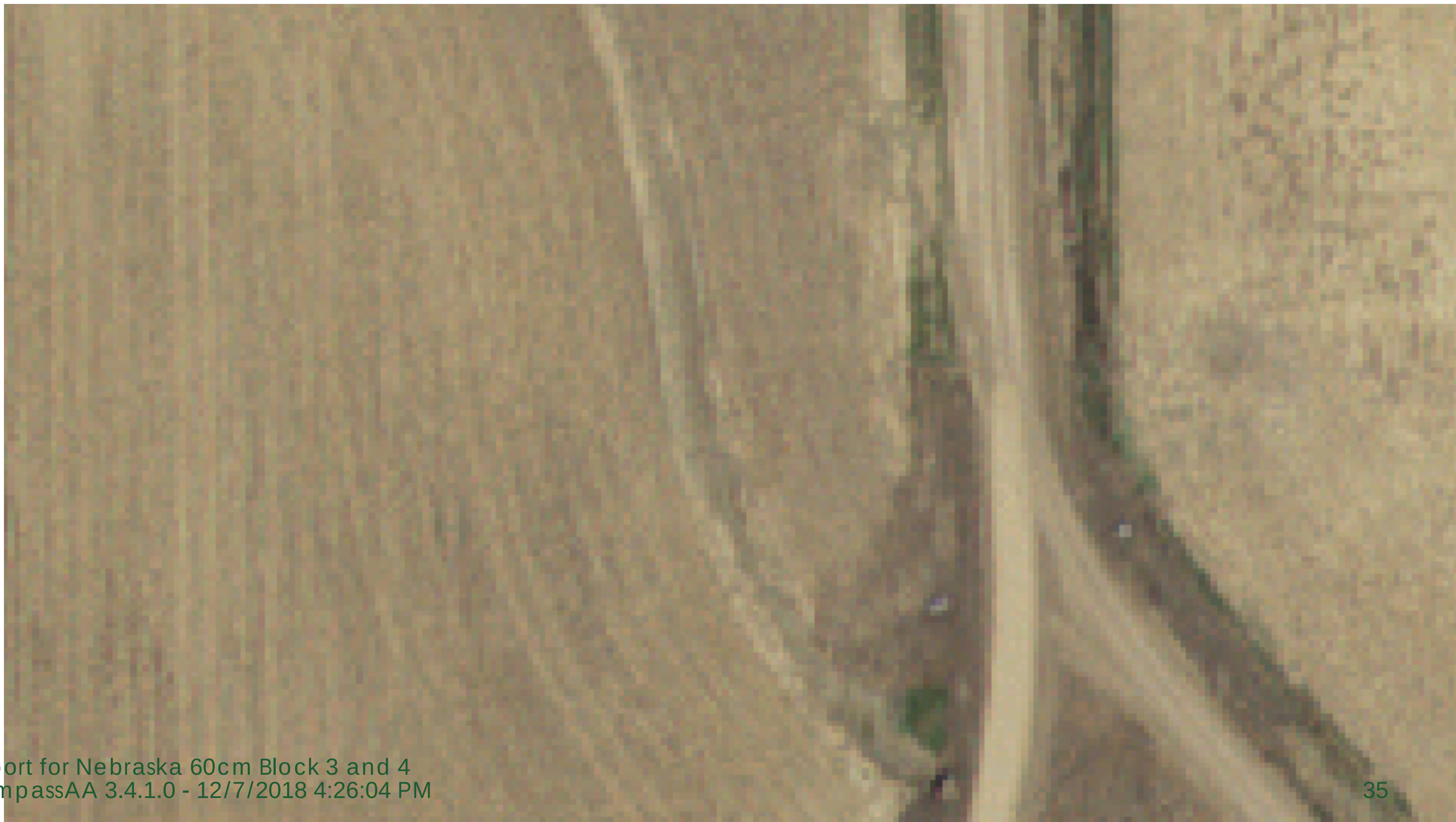
## Point CAL3034:

**X1: 606065.813 Y1: 4486732.136 Reason For Exclusion: Ambigious Location**



## Point CAL3047:

**X1: 602684.937 Y1: 4498013.685 Reason For Exclusion: Ambigious Location**

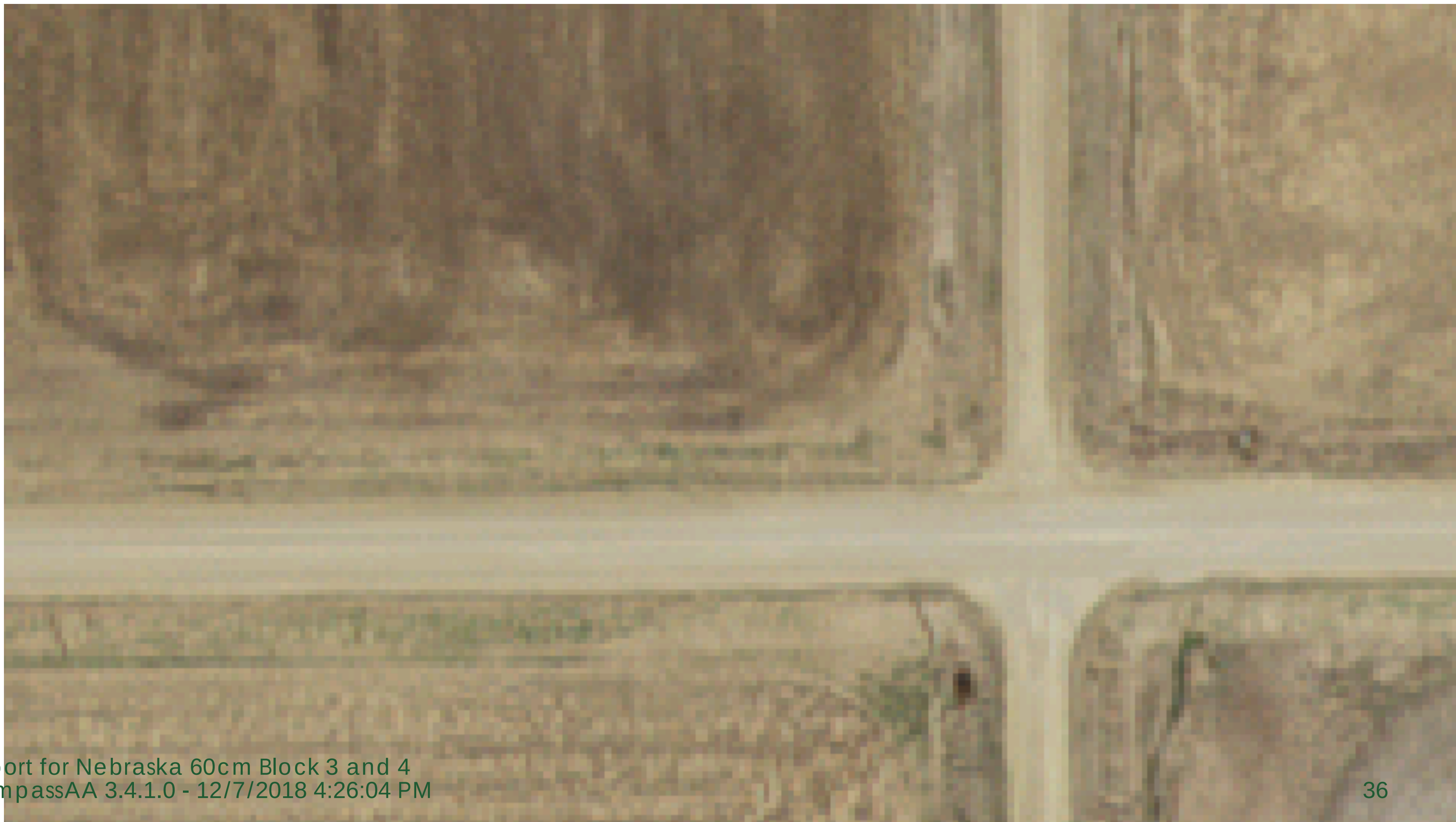


## Point CAL3051:

**X1: 620768.091 Y1: 4469251.703 Reason For Exclusion: Ambigious Location**

## Point CAL3011:

**X1: 640599.128 Y1: 4616203.153 Reason For Exclusion: Ambigious Location**



## Point CAL3024:

**X1: 608607.956 Y1: 4605992.393 Reason For Exclusion: Ambigious Location**

## Point CAL_extra_platte:

**X1: 627728.172 Y1: 4620847.869 Reason For Exclusion: Ambigious Location**

## Point CAL3049_alt:

**X1: 641158.85 Y1: 4475545.866 Reason For Exclusion: Ambigious Location**

## Point CAL3014:

**X1: 709818.31 Y1: 4548392.541 Reason For Exclusion: Ambigious Location**

## Point CAL3016:

**X1: 716114.571 Y1: 4555022.368 Reason For Exclusion: Ambigious Location**

## Point CAL3023:

**X1: 686063.094 Y1: 4583287.547 Reason For Exclusion: Ambigious Location**

## Point CAL3025:

**X1: 685121.847 Y1: 4559104.39 Reason For Exclusion: Ambigious Location**

## Point CAL_EXTRA_SAU:

**X1: 698593.744 Y1: 4561103.559 Reason For Exclusion: Ambigious Location**

## Point CAL3018:

**X1: 638734.138 Y1: 4545279.45 Reason For Exclusion: Ambigious Location**

## Point CAL3109:

**X1: 650794.425 Y1: 4545481.826 Reason For Exclusion: Ambigious Location**

## Point CAL3110:

**X1: 673978.234 Y1: 4545941.814 Reason For Exclusion: Ambigious Location**

## Point CAL_extra_sew:

**X1: 674268.027 Y1: 4534671.783 Reason For Exclusion: Ambigious Location**

## Point CAL3044:

**X1: 606704.677 Y1: 4539866.952 Reason For Exclusion: Ambigious Location**

# Appendix 3

**Following is a more detailed Survey Report**

CompassData

# Geodetic Survey Report

**CDI Project:** **5420 Nebraska II**

**CDI POC:** **Philipp Hummel**
**phummel@compassdatainc.com**

**Location of Survey:** **Nebraska**

**Date of Survey:** **February 2018**

**Customer:** **Merrick**

**POC:** **Doug Jacoby**

**MERRICK Project Name:** **NE_NRCS_OrthoLidar_2017_D18**

**MERRICK Task Order Number:** GPSC3 TO 014G0218F0028

**MERRICK Subcontract Number:** **65213751-A**

**Other Documents:** **CompassData-Nebraska II-SAPS_CDI Executed.pdf**

**Survey Report prepared by Philipp Hummel, PLS, CFedS, CP**
**phummel@compassdatainc.com**

CompassData

**Table of Contents**

# Contents

# Datum Requirements

Contractual requirements for the survey by the client:

Projection: Universal Transverse Mercator (UTM), Zones 13N, 14N, and 15N (where appropriate), Meters.

Horizontal Datum: North American Datum of 1983 (NAD 83), National Adjustment of 2011 (NA2011)

Vertical Datum: North American Vertical Datum of 1988 (NAVD 88); using the latest NGS-approved geoid (i.e., GEOID12B) for converting ellipsoid heights to orthometric elevations

# Surveying Methods

The combination of static Global Navigation Satellite System (GNSS) observations, and Virtual Reference Station (VRS) GNSS observations resulted in the highest accuracy of the coordinates. The CompassData standard field procedures for VRS observations require a minimum of two 90 second collects at each point. Between the two observations the GNSS unit was rotated by 180 degrees and re-setup (to neutralize any potential tilt bias). All survey observations by CompassData were taken with Trimble GNSS units (R10 and R8). When no Trimble VRS Now and cell service was available, static GNSS observations were collected for a minimum of 45 minutes. Figure 1 below shows the coverage map of the Trimble VRS Now network. The Trimble VRS Network is also known as a Realtime Kinematic Network (RTN).

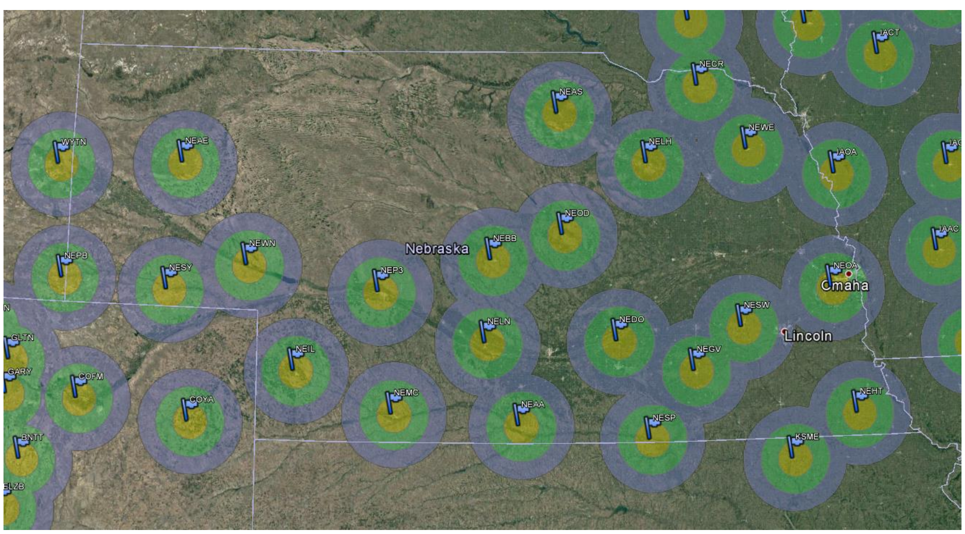



**Figure 1: Trimble VRS Now Network**

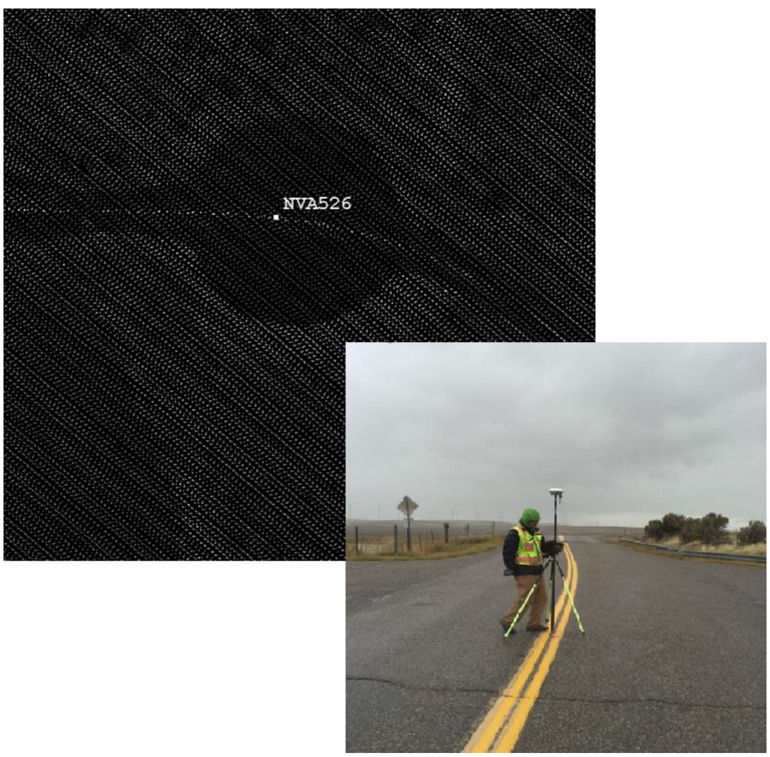
For the final coordinate values, a constrained network to continuously operating reference stations (CORS) was established. CORS stations are operated by the National Geodetic Survey (NGS). The constrained network anchors the VRS observations and static GNSS observations together. See Figure 2 below.

## Calibration, NVA and VVA Points

For the most part, CompassData field crews surveyed the suggested locations as planned per the client provided GoogleEarth files. Some locations were moved up to 1-2 km from the original locations due to landowner concerns and highway safety issues. Calibration and NVA (Non-vegetated vertical assessment) points were planned to fall on flat hard surfaces types: asphalt, concrete, gravel, and dirt roads. Due to the rural landscape of the Nebraska II, most points are on gravel and dirt-roads. The vegetated vertical assessment points (VVAs) fell on different types of grasses that are common to the Nebraska II prairie. The different grasses will probably have similar LiDAR signal returns if measured before summer; slight differences can still be expected at some of the locations due to taller and denser grass. Five photos provided for each VVA point show the density and height of the grass.  Some of the areas had been recently flattened by snow and wind.

## Horizontal Accuracy Intensity-Identifiable Features

CompassData field crews surveyed 62 intensity-identifiable features as NVA or calibration points. The intensity-identifiable features were surveyed when it was feasible, meaning when road markings on asphalt were available and accessible to survey without having to place a GNSS unit into traffic for an extended time.



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## Post-Processing Procedure

The Nebraska II project area covers about a large portion of Nebraska and is subdivided in 3 separate areas. Post-processing of GNSS data of such large areas is spilt into smaller areas for two reasons: The geometric distortions that potentially come with very large networks are kept at a minimum, and the organization of the work can be handled easier. With client approval, the Nebraska II project was split into the 20 counties covered by the project. For each county, the data was post processed with the following procedure.

The static data collected in the field was combined into a network adjustment with any VRS GNSS observations and the static GNSS from the closest CORS stations. Coordinates for the static points were established by a constrained network adjustment (Method of the Least Squares) and checked against Online Positioning User Service (OPUS) solutions. Such static observations were also conducted on VRS observations for quality control.

All points meet accuracy requirements of 6.5 cm for calibration and NVA points and 9.8 cm for VVA points with a 95% confidence (CE95).

## Distribution of Surveyed Points

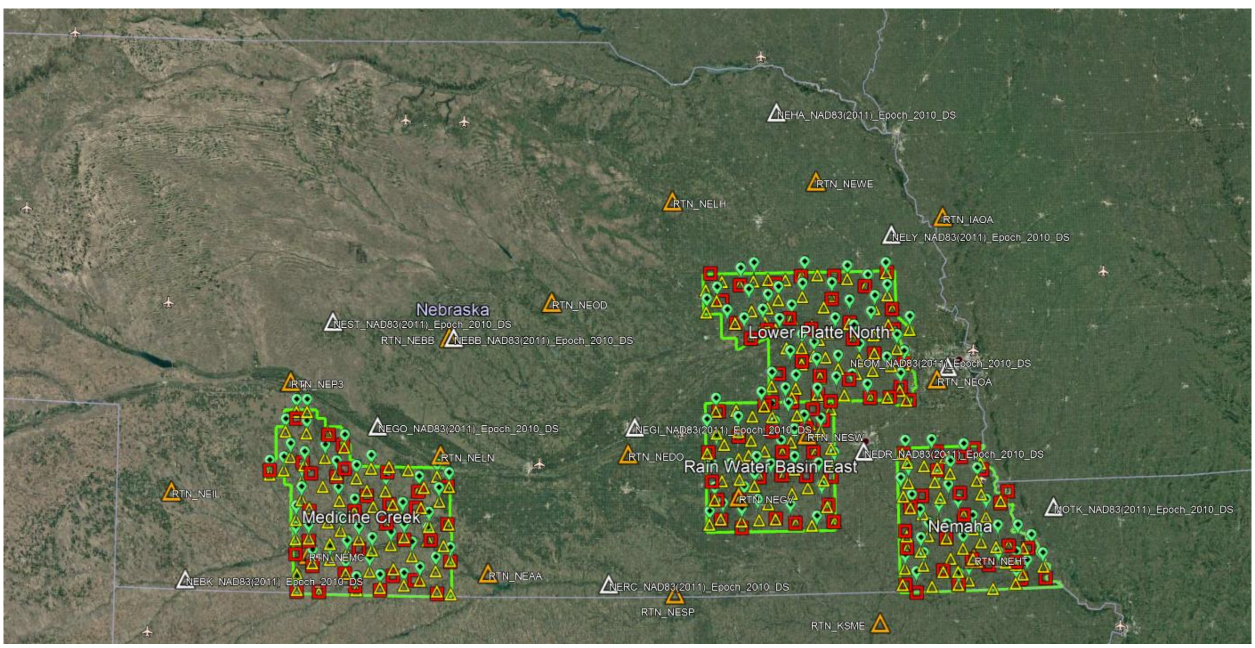


**Figure 2: Distribution of Calibration Points (Red), NVA Points (Yellow), and VVA Points (Green) and CORS Stations by the NGS (White) and Trimble VRS Now Stations (Orange)**

# Incorporated CORS stations from the NGS and Trimble VRS Now

As described above, all the different network adjustments per county are based on the same GNSS base stations provided by the NGS and Trimble VRS Now. The NGS stations have the published NAD83 (2011) coordinates that were used as fixed constrains to reproduce the official NAD83 (2011) geodetic datum. While the Trimble VRS Now stations are operated, and used by various professionals, these are not on the same geodetic network order of the NGS authoritative data.
The geodetic datum was further confirmed with physical NGS monuments. Published coordinates by the NGS and OPUS solutions were taken in account to confirm accuracy of equipment and the NAD83(2011) datum.

| Base Stations | Latitude | Longitude | HAE | NAVD88 |
|---|---|---|---|---|
| IADN_NAD83(2011)_Epoch_2010_DS | 41.99737861 | -95.37570247 | 351.173 | 380.427 |
| KSU1_NAD83(2011)_Epoch_2010_DS | 39.10074370 | -96.60947044 | 326.626 | 356.573 |
| MOSV_NAD83(2011)_Epoch_2010_DS | 39.95420768 | -94.84758805 | 320.921 | 352.668 |
| MOTK_NAD83(2011)_Epoch_2010_DS | 40.43725836 | -95.35121019 | 252.967 | 283.631 |
| NEAL_NAD83(2011)_Epoch_2010_DS | 41.67508023 | -97.98057042 | 511.322 | 535.788 |
| NEAP_NAD83(2011)_Epoch_2010_DS | 40.30585513 | -99.90537033 | 647.252 | 671.927 |
| NEBB_NAD83(2011)_Epoch_2010_DS | 41.40230124 | -99.62597833 | 737.868 | 760.589 |
| NEBK_NAD83(2011)_Epoch_2010_DS | 40.06140632 | -101.53103525 | 912.765 | 936.007 |
| NEDR_NAD83(2011)_Epoch_2010_DS | 40.77258105 | -96.70031784 | 349.329 | 375.304 |
| NEFR_NAD83(2011)_Epoch_2010_DS | 40.14815400 | -97.17067345 | 413.536 | 440.594 |
| NEGI_NAD83(2011)_Epoch_2010_DS | 40.92225342 | -98.32815271 | 542.597 | 567.688 |
| NEGO_NAD83(2011)_Epoch_2010_DS | 40.92006473 | -100.16589717 | 763.415 | 786.527 |
| NELY_NAD83(2011)_Epoch_2010_DS | 41.93825475 | -96.45930250 | 399.147 | 425.053 |
| NEMC_NAD83(2011)_Epoch_2010_DS | 40.19940227 | -100.57816530 | 740.680 | 764.713 |
| NEOM_NAD83(2011)_Epoch_2010_DS | 41.21556233 | -96.08039169 | 351.506 | 378.703 |
| RTN_KSME (Trimble VRS Now) | 39.84114023 | -96.60904227 | 374.580 | 402.670 |
| RTN_NEAA (Trimble VRS Now) | 40.13243889 | -99.37050533 | 612.381 | 637.593 |
| RTN_NEGV (Trimble VRS Now) | 40.54019464 | -97.59491297 | 473.879 | 500.555 |
| RTN_NEHT (Trimble VRS Now) | 40.17365704 | -95.93323735 | 295.277 | 324.801 |
| RTN_NELH (Trimble VRS Now)* | 42.13799508 | -98.04607500 | 516.535 | 541.179 |
| RTN_NELN (Trimble VRS Now) | 40.76824037 | -99.71205248 | 708.802 | 732.678 |
| RTN_NEMC (Trimble VRS Now) | 40.21562091 | -100.64948606 | 792.842 | 792.842 |
| RTN_NEOA (Trimble VRS Now) | 41.15075323 | -96.16077923 | 337.973 | 364.812 |
| RTN_NEP3 (Trimble VRS Now) | 41.15071658 | -100.79944327 | 845.943 | 868.070 |
| RTN_NESW (Trimble VRS Now) | 40.86854026 | -97.10255165 | 437.918 | 464.836 |

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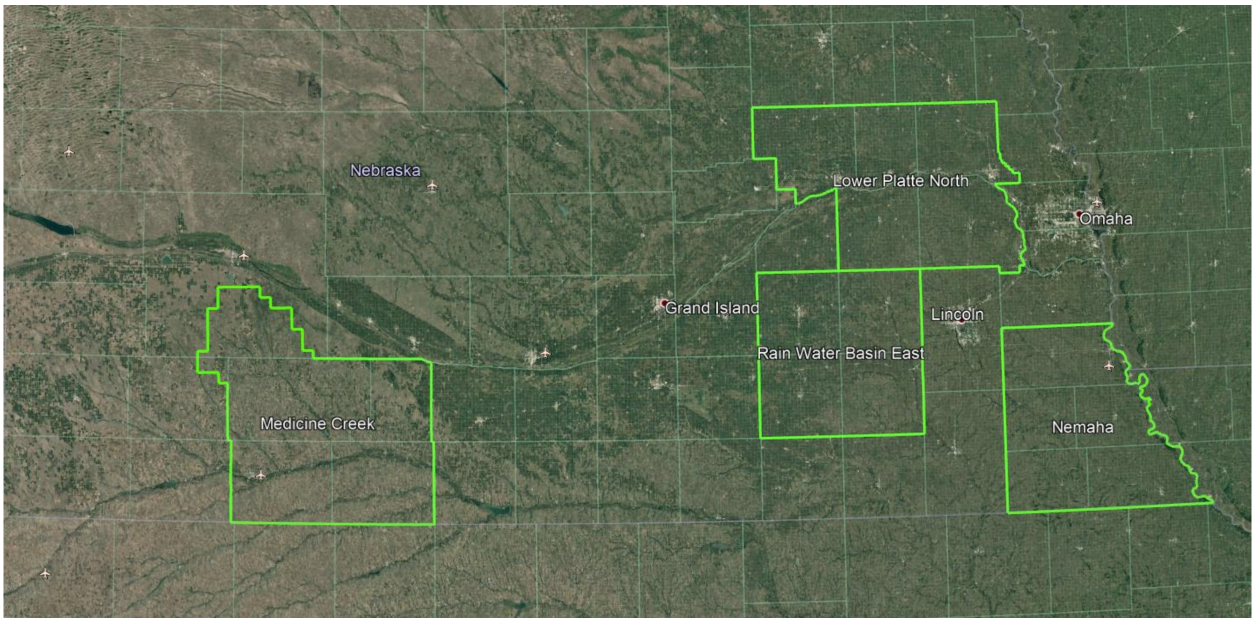
|---|---|---|---|---|
| RTN_NEWE (Trimble VRS Now) | 42.23424649 | -96.99916201 | 421.039 | 445.955 |
| RTN_IAOA (Trimble VRS Now)** | 42.02647890 | -96.08125941 | 298.973 | 326.202 |

Note above *: The Trimble VRS Now base station NELN in Lexington was changed since the Sandhill survey. Note above **: The Trimble VRS Now network operates in Onawa, IO, a base station IAOA that was introduced later to the processing of Dodge County (northeast corner of AOIs). The coordinate was established in the Dodge county network adjustment.

## AOI and Regions of Nebraska II Project

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